Research

MICHIGAN TECHNOLOGICAL UNIVERSITY / 2019

THIS ISSUE

SLEEP

We sleep one third of our lives. Big data reveals why our hearts need plenty of sleep, which may matter more to women than men.

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REGULAR FEATURES

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

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RESEARCH HIGHLIGHTS 2018

Between 2017 and 2018, Michigan Tech's research expenditures grew 9.8 percent, totaling more than $78 million. The number reflects the University's expanding expertise in Great Lakes research, mobility, remote sensing, and health sciences.

Above water: The Great Lakes Research Center oversees the Marine Autonomy Research Site (MARS) in Lake Superior, the first freshwater test bed of its kind. It is part of the Smart Ships Coalition, which brings together researchers, policy makers, and resource managers to study and set ground rules for the use of autonomous marine vehicles on the Great Lakes.

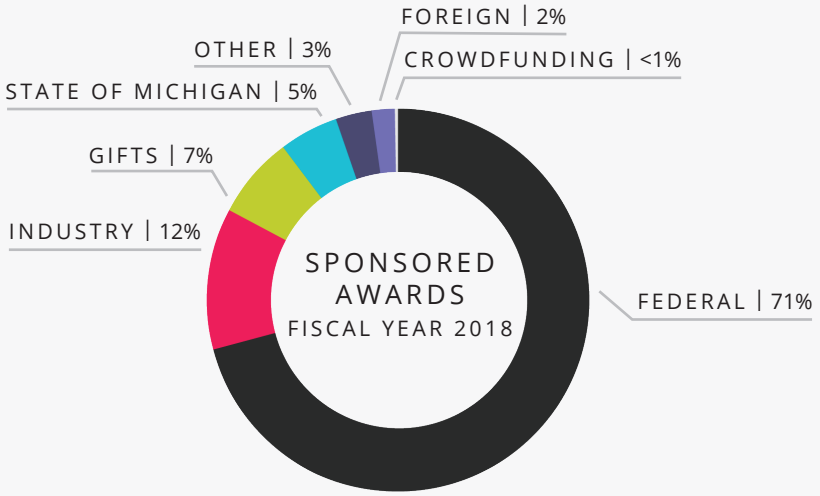
Navigating risk: In January 2018, the State of Michigan placed Michigan Tech at the helm of an independent risk analysis of the Straits Pipelines. The 41-person team looked at 4,380 simulations of "worst-case-scenario" spills.

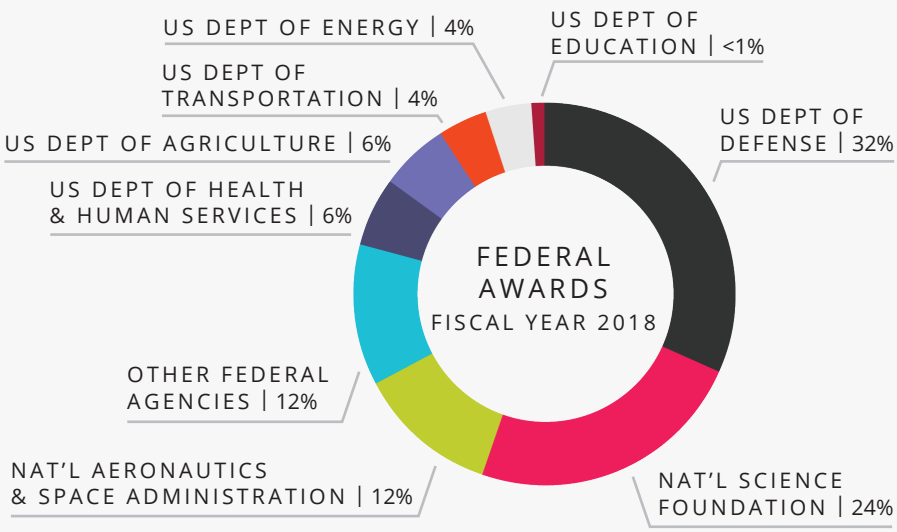
Eruptions: More than 10 faculty, grad students, and alumni responded to the eruptions in Hawaii and Guatemala. Seismic surveys and remote sensing data help geoscientists better understand volcanoes, their plumbing systems, their emissions, and evacuation protocols to keep people safe.

Stream gauges: Following the June 2018 flash floods that hit the Keweenaw Peninsula, Michigan Tech ecologists worked with state and federal agencies to advocate for reinstalling local stream gauges. Better data means better predictions for events like last year's 1,000-year storm.

Traffic signals: The Michigan Department of Transportation installed five upgraded traffic signals in Houghton that provide a local corridor where engineers can safely study vehicle-to-infrastructure (V2I) technology and communication.

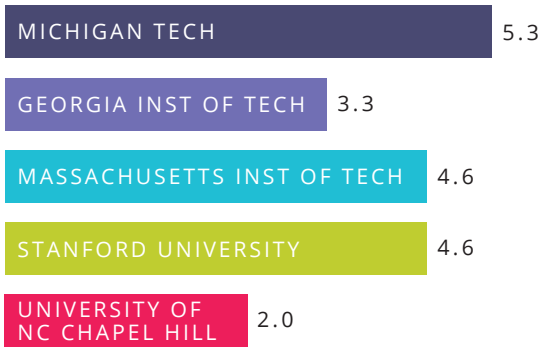
Research Statistics





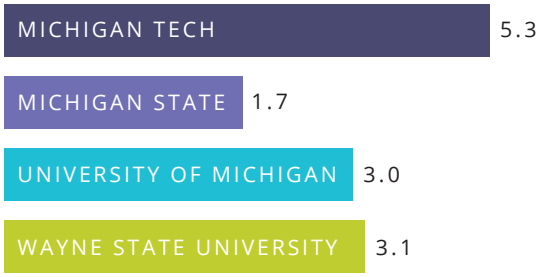
2017 INVENTION DISCLOSURES PER $10 MILLION OF RESEARCH EXPENDITURES

(COMPARED TO BENCHMARK UNIVERSITIES)



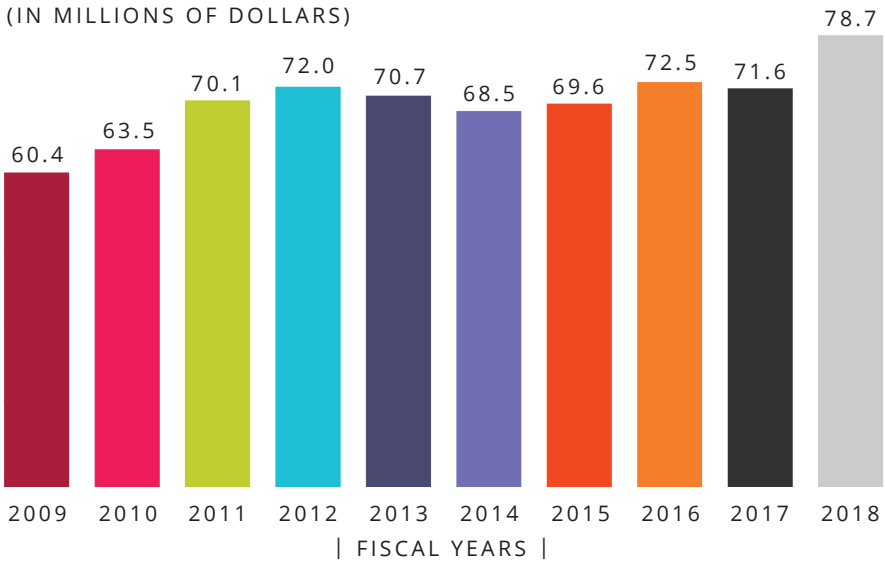
2017 INVENTION DISCLOSURES PER $10 MILLION OF RESEARCH EXPENDITURES

(COMPARED TO MICHIGAN UNIVERSITIES)



RESEARCH EXPENDITURES

(IN MILLIONS OF DOLLARS)



$78,678,397
TOTAL 2018 RESEARCH EXPENDITURES

9.8%
INCREASE OVER FISCAL YEAR 2017

18
RESEARCH CENTERS AND INSTITUTES

277,684
SQUARE FEET OF RESEARCH SPACE

Research IN BRIEF

NOT JUST A DAD SPORT

More young women are buying fishing licenses in the Great Lakes region, while the number of male anglers is generally declining. The finding is one of several in a new study exploring regional demographics of fishing.

Richelle Winkler, associate professor of sociology and demography and the principal investigator for the study, with doctoral candidate Erin Burkett, examined changes in the angling population by looking at recent trends in anglers through various demographic lenses, such as gender, age, and generational differences.

Each year, approximately 1.8 million recreational anglers fish the Great Lakes. Millions more fish inland lakes and streams across the Upper Great Lakes region. Anglers play a critical role in the region's fisheries, their related ecosystems, and fisheries management practices and policies.

>>>Find out what the changing face of anglers means for fisheries management: mtu.edu/greatlakes/fishery

ADVANCING FACULTY CAREERS

A more diverse STEM workforce starts with more diverse faculty. To make that a reality, an interdisciplinary campus team has a goal: measurable increases in retention and career advancement of women and under-represented minorities at Michigan Tech within the next three years. Among the initiatives are career development teams, programs addressing intersectional disadvantages, and managerial training for chairs.

The National Science Foundation has granted $1 million to Michigan Tech faculty Adrienne Minerick, Patty Sotirin, Sonia Goltz, Andrew Storer, and Audrey Mayer to continue the work of existing programs and implement new ones based on other university programs.

"We are inspired by, but not bound to, the work of similar teams on other campuses," Sotirin says. "We look forward to the collaborative development of programs that are responsive to our uniqueness and that open new possibilities for campus culture change, equity, and success."

>>>Learn more about the ADVANCE program: mtu.news/2NtOYog

GLIMPSE THE STARS

Robert Nemiroff, professor of astronomy and astrophysics, co-created the Astronomy Picture of the Day (APOD) website with Jerry Bonnell, a fellow astrophysicist and staff scientist at NASA's Goddard Space Flight Center working on the Fermi Gamma-ray Space Telescope team. Nemiroff and Bonnell track down, post, and explain images that endeavor to inspire a spirit of curiosity and open the eyes of viewers to the myriad opportunities to take a voyage through space via photography.

APOD, translated into more than 20 languages, typically receives more than 800,000 views with a social media following of more than 1.3 million people, popularizing science and inspiring a love of astronomy.

>>>Enjoy the view from this "Small and Drifting Planet" in an *Unscripted* photo essay: mtu.news/2BzTZEm

The Sabana Research Station, Luquillo, Puerto Rico.


Tana Wood


Tana Wood

BEFORE AND AFTER: HURRICANES IRMA AND MARIA HIT PUERTO RICO

When Hurricanes Irma and Maria carved their destructive paths across the Caribbean, they left behind grieving communities without power, badly damaged homes and infrastructure, and completely altered ecosystems. One of these was the El Yunque National Forest, on the northeastern side of Puerto Rico.

El Yunque is the only tropical forest in the US Forest Service (USFS) system, which makes it ideal for understanding the effects of climate change where those changes will impact the most. Molly Cavaleri, associate professor of tree physiology in the School of Forest Resources and Environmental Science, is leading Tropical Responses to Altered Climate Experiment (TRACE), a USFS and Department of Energy (DOE)-funded project, with fellow researchers Tana Wood from the USFS, and Sasha Reed with the US Geological Survey.

When Irma passed the island, the forest canopy where the TRACE project is located was patchily damaged. Hurricane Maria finished the job, and marred project equipment at the same time.

These events left the researchers wondering how to move the project forward now that many, if not all, of the parameters had been dramatically altered.

"When you walk into what was previously a closed-canopy forest, it's hot, there's no shade, and the forest is basically reset," Cavaleri says of her visit to El Yunque Experimental Forest in January 2018.

Cavaleri has pivoted the project with her co-investigators into a warming and disturbance regime study—the only one of its kind in the world.

"We got four good years of data," Cavaleri says. "I'm so grateful my whole lab was there all summer. I had three undergraduates there doing projects, my PhD student was doing a project all summer, and they finished a full campaign. They got back a week before the first hurricane hit. We were lucky."

Cavaleri and her team secured a DOE Office of Science grant to document and study the disturbance and recovery of the El Yunque TRACE site. They will also continue their work on detailing the effects of rising temperature impacts on tropical forests and carbon storage through above- and below-ground processes.

>>>Follow the TRACE experiment: forestwarming.org

Research IN BRIEF

THE MICHIGAN LEGISLATURE HAS GRANTED PLANNING AUTHORIZATION FOR A NEW H-STEM ENGINEERING AND HEALTH TECHNOLOGIES COMPLEX ON CAMPUS. THE FOLLOWING PROJECTS, MANY FUNDED BY THE PORTAGE HEALTH FOUNDATION, WILL USE THE SPACE TO CREATE TECHNOLOGICAL SOLUTIONS TO ENHANCE HUMAN HEALTH AND QUALITY OF LIFE.

ALZHEIMER'S

What if cognitive decline could be detected early with motor skill learning tests? That's the focus of a new National Institutes of Health study led by Kevin Trewartha, assistant professor of cognitive and learning sciences, as well as kinesiology and integrative physiology. His team uses robotic handles and augmented reality screens to gauge how well patients think about and learn new physical skills, which may reflect early signs of cognitive impairment.

>>>Learn what kind of tech the team hopes will help doctors: mtu.news/2wXJgRw

CANCER

Cells need carbohydrates; facilitative glucose transporters (GLUTs) bring nutrients in and out of cells. GLUTs are the foundation of research by Marina Tanasova, assistant professor of chemistry. In partnership with Smitha Rao, assistant professor of biomedical engineering, they test GLUT-based fluorescent probes to detect cancer and distinguish one type from another, providing a fingerprint of the disease.

SKIN

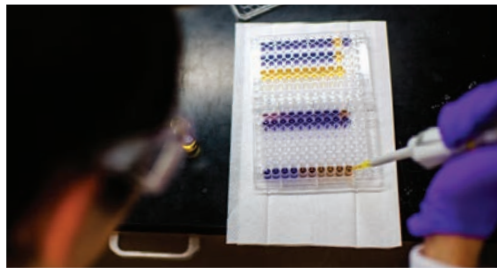
Lasers can help skin-firming serums and anti-wrinkle creams. Sean Kirkpatrick, professor and chair of the Department of Biomedical Engineering, designs laser technology to measure the effectiveness and longevity of beauty products. He partnered with Avon to create and test experimental formulas quickly and without relying on subjective feedback from focus groups.

>>>Watch how laser diffraction patterns detect skin firmness: mtu.news/2vmOKXz

VACCINE

Virus-like particles (VLPs) are empty viral shells formed by structural proteins. In vaccines, they elicit immune responses and are noninfectious, but can be fragile. Ebenezer Tumban, assistant professor of biological sciences, uses bacteriophage VLPs as platforms to develop vaccines against viruses such as human papillomaviruses (HPV), Zika virus, and Chikungunya virus. He uses the FEI 200kV Titan Themis Scanning Transmission Electron Microscope (STEM) to assess whether the structural proteins can assemble into VLPs and whether assembled VLPs are stable after storage at room temperature for months.

>>>Look at VLPs under a microscope with the high-powered STEM: mtu.news/2QbrHst



WOUNDS

Nitric oxide and hydrogen peroxide are two healing compounds the body naturally makes to help close wounds. Megan Frost, associate professor of biomedical engineering, leads a team using nitric oxide technology to drop the healing time for diabetic foot ulcers from 150 days to 21. She joined Bruce Lee, assistant professor of biomedical engineering, and Caryn Heldt, James and Lorna Mack Chair in Bioengineering in chemical engineering, to test a microgel powder. While making smart glue, Lee's team discovered a handy byproduct: hydrogen peroxide. In microgel form, it reduces bacteria and virus ability to infect by at least 99 percent.

>>>Healing with nitric oxide is a cell-mediated symphony of complexity: mtu.news/2DE4nNI

>>>Healing with the sticky amino acids in mussel feet: mtu.news/2zaUiUr

TIME TRAVELER

Don Lafreniere, associate professor of geography and geospatial information sciences (GIS), and Sarah Fayen Scarlett, assistant professor of history, travel through time.

It started in 2013 when Lafreniere co-authored a paper about a concept called deep mapping: Projects curated by scholars that offer the public a spatial playground to explore open-ended questions about a particular place across time. Deep maps allow multiple representations of a place, rather than a solitary cartographic concept created by a single person, to weave rich narratives that would otherwise be lost to antiquity.

Deep maps are built on scaffolds of spatial data, which include contemporary and historical records from census data, personal narratives, photographs, environmental information, and more. In the paper, Lafreniere wrote about the possibilities of deep mapping for both academics and the public.

In 2015, Lafreniere, Scarlett, and collaborator Robert Pastel, associate professor of computer science, and other colleagues, including local heritage partners, embarked on a journey to create the first deep map. The Keweenaw Time Traveler, the public-facing application of the Copper Country Historical Spatial Data Infrastructure, allows users to contribute to an online interactive historical atlas of the Keweenaw Peninsula. The project starts conversations—online and in person—about the region's industrial past and how it continues to affect lives and identities today.

"This project brings together qualitative and quantitative information and allows multiple interpretations about the past," Lafreniere says. "We asked ourselves, how can we build an infrastructure that allows researchers to study social mobility, immigration, and segregation, as well as allow a framework for the public to share their stories about how these things played out?"

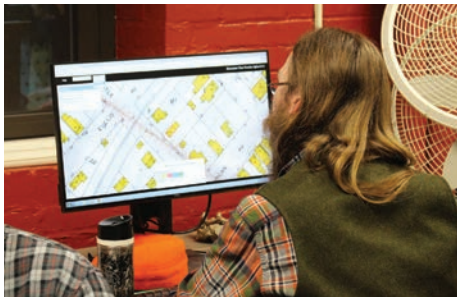
The Time Traveler embeds users in more than 60 years of historical maps, images, and contributed stories. It's a compendium of big historical data sets. The public uses it and so do Michigan Tech researchers. They work to understand industrial contamination patterns and for geoheritage tours. To manage relief efforts in Ripley, Michigan, after the June 2018 floods, the Federal Emergency Management Administration (FEMA) examined historical land uses.

The next steps include continuing to improve the functionality of the program and the expansion of stories within the Time Traveler's Explore app. For example, how has Michigan Tech's campus evolved, and how did the lives, professions, and personal contributions of certain people influence change?

"It's our hope that people use the platform to better visualize the data they need to answer their questions, to think of new questions, or to learn something they didn't know about the area," Scarlett says. "When people feel more connected to the places where they live, they usually make better connections with each other."

Explore the Keweenaw's history for yourself: keweenawhistory.com

>>>Watch the Time Traveler in action: mtu.edu/magazine/traveler



Data, shown via maps and overlays, connects people to place and history.

BY THE NUMBERS

630 Stories contributed in the Explore app

259K Classifications of map features by citizen historians

17.4M Variables about people and places across space and time

SLICE OF LIFE

Chinese. Greek. African American. Native American. Summer fieldwork uncovers deep, delicate (and sometimes muddy) history.

Corner of Oak and 9th, Calumet, Michigan. Across from the train station; built in 1885, demolished in the 1960s. But humans lived here for as long as 2,000 years before the 818 Oak Street address.

Timothy Scarlett, associate professor of archaeology and anthropology, expected students conducting a two-week survey to uncover artifacts from the Chinese laundry that was also a grocery, boarding house, and community center for Chinese immigrants. Starting in 1905, the owners—who included Chung Wang, Chin Hee, and Wo Chung, speculated to be the men in the photo below—leased to Greek immigrant cobblers. As Scarlett says, "It was a big home, and people lived tight." Life was not easy. Discriminatory laws. Sweeping immigrant arrests. The home's façade ripped off the building after being chained to a train. By 1916, all Chinese residents departed.

From 1927 to 1944, an African-American family set up house: Lulu Fowler Gardner and her kin. The home passed through other hands, including the State of Michigan in 1958 and final owner Socrates Antioho.

"People dig up deeper, older layers, and mix them with new trash. Soils grow and are buried," says Scarlett. "The detritus of daily life builds, and leaves us clues to find as we peel back the layers."

Michigan Tech Archives

LEVEL 1

CERAMIC FRAGMENTS
LEVELS 1 & 2

Fragile Woodland-era pottery, made sometime in the last 2,000 years, was a shocking discovery. The shards were found close to the surface, about 20 cm deep. The shallow depth suggests that builders unearthed them while excavating the cellar. Another site lies beneath.

LEVEL 2

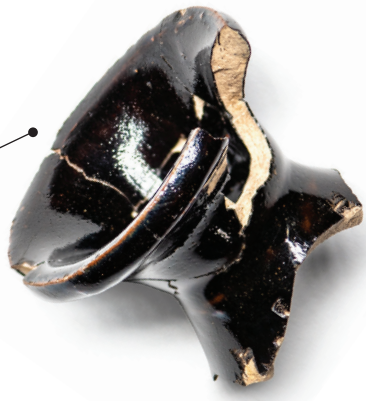
TEAPOT SPOUT
LEVEL 2

Late 19th-century porcelain. "We don't know who these people are yet," Scarlett says. Names were often approximations. "Census enumerators were notoriously inaccurate when counting immigrants and people of color. We must also dig deeply into archives and oral histories."

LEVEL 3

CHINESE STONEWARE
LEVEL 4

Neck and lip of a 19th-century liquor bottle. Found while excavating deeper, basement rubble; other artifacts were unearthed from yard spaces. Clear photos of the house are lacking; it was usually obscured by wooden fences plastered with billboards—profitable ad space facing the train station.



LEVEL 4

LEVEL 1

LEVEL 2

LEVEL 3

LEVEL 4

BLUE BEAD
LEVEL 1

Beads—often blue—have long been important symbols in African-American culture. Adornment or talisman, beads convey social meaning, including wealth, age, marital status, and political and religious affiliations. Blue is a color of protection and security.

PURPLE GLASS
LEVEL 1

Lampshade or candy dish, an artifact representing middle-class stability and refinement. Fowler Gardner kept the home as a boarding house and her husband, John, was a traveling barber. The artifact's domesticity belies the stereotypical image of a poor, working-class household.

SHELLAC RECORD
LEVEL 1

Yodeling cowboy or big band fox trot? Stamped catalog numbers indicate two 1930s possibilities: "Rambling Yodeler" by Cliff Carlisle or Jerry White Hoffman's Hollywood Dance Orchestra, "While I am Here and You are There (How Can We Get Anywhere)."

PUNCHED COIN
LEVEL 1

Holes to string it for safekeeping, to wear, to hang? The answers hinge on two pivotal questions used to evaluate potential historical sites for further archaeological exploration and funding: Is it significant? Is it intact? The answer to both, Scarlett says, is yes.

PORCELAIN SHARD
LEVEL 2

"Geisha pattern" china was marketed to blue-collar American households. Common find in mining towns, historically Chinese neighborhoods, and the trash of working-class households. "Each fragment becomes a pixel in an increasingly detailed picture of people's lives," says Scarlett.

LITHIC FLAKE
LEVEL 2

Shallow find with age: tool-making scraps. Native American toolmakers used microcrystalline silicate, flint, agate, or chert rocks for scrapers, knives, points, flintlock weapons, and fire starters during "pre-matches" eras. Students will try to "refit" the flakes to understand the maker's process.

3 PERCENT FOR THE PLANET

Peatlands cover 3 percent of land and store 30 percent of soil carbon.

A peatland near the Pastoruri Glacier in Huascarán National Park, Peru.

Called swamps, bogs, marshes, muskegs, and quagmires, peatlands are much more than wet, low-lying areas. Despite such ignoble nomenclature, the planet needs peatlands.

"All ecosystems store carbon, but wetlands store a lot more than all the rest," says Rod Chimner, professor in the School of Forest Resources and Environmental Science. Peatlands cover just 3 percent of the Earth's land, but store approximately 30 percent of the Earth's soil carbon. When peatlands degrade, the carbon releases into the atmosphere, which contributes to climate change. Following the October 2018 publication of the Intergovernmental Panel on Climate Change's most recent report, the need for carbon sequestration to fight rising global temperatures is more imperative than ever to prevent catastrophic climatic changes.

Peatlands occur across the planet in low-lying boreal, temperate, tropical, and even mountainous regions. Mountain peatlands thrive where it's cool and wet, perfect conditions for slow decomposition of organic material—the process by which peat is created.

Nestled in the high valleys between the 20,000-foot peaks of the Andes, the peatlands of Colombia, Ecuador, Peru, and Bolivia do more than act as carbon sinks. They also purify water as it travels from the mountains to the arid cities along South America's western coast, cycle nutrients, and provide grazing areas for native camelids like llamas, alpacas, *guanaco*, and *vicuña* as well as cattle and horses.

Overgrazing and other human activities lead to peatland degradation around the world. Chimner explains that for global carbon accounting to remain balanced, peatlands need to function as carbon-capture systems, and the nations where peatlands occur need tools to protect them.

MEASURING

Chimner's work in the Andean peatlands is in partnership with the Sustainable Wetlands Adaptation and Mitigation Program (SWAMP), a joint program through the Center for International Forestry Research, the US Forest Service (USFS), Michigan Tech, and Oregon State University with funding support from the US Agency for International Development. Chimner first came into partnership with SWAMP through his past work on Andean peatlands funded by a National Geographic Society Research Exploration grant.

As the effects of climate change increasingly impact people's daily lives, many nations see value in measuring their carbon stocks—the amount of carbon stored in a given area—and taking steps to ensure the carbon is not released into the atmosphere. One of SWAMP's primary goals is to help nations quantify their carbon stocks—a process that involves coring peat samples, *in situ* gas emission analysis, and extensive mapping.

Coring peat is more than a scientific endeavor; it's also a great workout. Using a Russian peat corer, which is a side-cutting auger made of aluminum, Chimner, a post-doctoral researcher, and graduate students extract peat 50 centimeters (approximately 1.6 feet) at a time, delving as deep as 11 meters (approximately 36 feet).

Twist, twist, twist, side cut, lift the sample out. Add five-foot handle sections to continue going deeper into the peat. Attach a carjack to help pull the increasingly long corer out of the ground. Stop to admire the scenery because it's breathtaking—and so is the coring effort, which frequently occurs at 14,000 feet in elevation or higher.

The team chunks the 50-centimeter (20 inches) sections into 10-centimeter (4 inches) samples to analyze in the lab for mass, percent carbon, and bulk density to calculate total carbon stocks. The samples are like fine compost, but old roots add structure to the peat so it isn't crumbly. They use radiocarbon dating to calculate a peatland's age and how fast it accumulates peat.

Rod Chimner

Rod Chimner, John Hribljan, and master's student Ana Maria Planas Clarke coring an 11-meter (36 feet) deep peatland in Los Nevados National Natural Park, Colombia.

Rod Chimner

For reference, Indonesian peatlands are known as the deepest in the world. They are capable of storing upwards of 3,000 megagrams per hectare of carbon—which is 3 million kilograms (roughly 6.6 million pounds) of carbon in an area one-kilometer square (.38 miles square), or the equivalent of stacking 1,743 sedans in a suburban backyard.

Michigan wetlands store about 1,200 megagrams per hectare of carbon, while peatlands in the Amazon store slightly less than 2,000. Mountain peatlands are capable of storing up to 4,000.

Here and there, too, are gray layers in stark contrast to the darker peat. These ash layers accumulated from volcanic eruptions, which scientists use like mile markers to accurately date the age of the peat. Once, while coring in Colombia, Chimner's Colombian guide said they were the only people in Los Nevados National Natural Park—because it had been closed due to volcanic activity.

Moving south through Andean ecosystems, the vegetation changes dramatically from the rainy *páramo* of Colombia and Ecuador to the drier *puna* of Peru and Bolivia. Colombia's and Ecuador's peatlands are frequently comprised of sedges, grasses, and cushion plants—a misleading name as the green, hump-like mounds are quite hard because they are adapted to high, cold, and windy areas. A human can walk across them, but the hooves of grazing animals can break down the mounds. The *páramo*'s weather presented a challenge to sampling because the constant rain blurred the landscape, making it difficult to distinguish the peatlands.

"NO ONE EVER THOUGHT THESE MOUNTAINS WOULD HAVE THIS MUCH CARBON. THEY HAVE SOME OF THE HIGHEST STORING CAPABILITIES IN THE WORLD."
—ROD CHIMNER

In Southern Peru and Bolivia, the arid conditions made it easy to find the wetlands, but the many wet meadows interspersed with the peatlands had similar vegetation, again making distinguishing the two difficult. However, the carbon stocks of wet meadows are much smaller than the peatlands, so classifying them correctly is important to accurately calculate carbon stocks. Confusing matters in the field, wet meadows and peatlands are frequently called by the same name—*bofedales*—and Chimner says this has befuddled land managers, scientists, and carbon stock accounting in the past. To distinguish wetland types, Chimner and others are combining soil samples with other methods, including ground-penetrating radar and extensive remote sensing mapping.

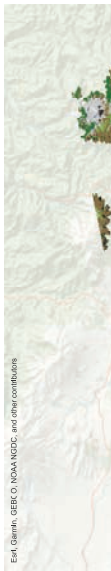
In addition to mapping peatlands, three long-term research sites were monitored in Colombia, Ecuador, and Peru to quantify greenhouse gas emissions in areas unaltered by humans or grazing, and those that provide a picture of whether a particular peatland is acting as a carbon sink or a carbon source. Chimner and colleagues conduct greenhouse gas flux measurements using either eddy flux towers (which they are using currently in the Amazon) or chambers (which work better in small mountain peatlands). They look like large plastic terrariums placed on the peat. Infrared gas analyzers hook up to the chambers to measure carbon dioxide emissions and a portable, flame ionizing detector measures methane emissions. These are the first carbon cycling measurements from Andean peatlands.

The researchers found that the natural peatlands are still slowly accumulating carbon. But when degraded by either grazing or water diversion, the peatlands become a source of carbon to the atmosphere.

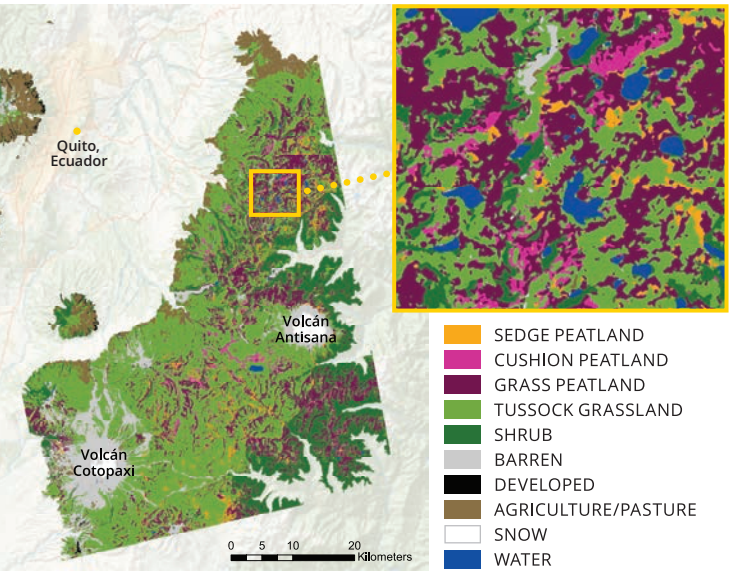
Cushion plant peatlands of the Andes have some of the lowest methane emission rates of any peatlands in the world. However, when degraded from cattle grazing, they became large sources of both carbon dioxide and methane, which doubles climate harm. Carbon cycling can be improved in degraded peatlands by restoring the peatlands.

MAPPING

Greenhouse gas measurements are point samples. And while Chimner and others have taken many point samples over the years, these samples must be extrapolated up to the country level to provide nations with carbon stock estimates. Using modeling



Laura Bourgeau-Chavez



tools and remote sensing in combination with point samples allows researchers to map wetlands on the landscape.

Laura Bourgeau-Chavez, research scientist at the Michigan Tech Research Institute, has undertaken creating national wetland maps for the project. Using field samples, radar, and multiple multidate remote sensing imagery sources—Landsat, PALSAR, Shuttle Radar Topography Mission (SRTM), and RADARSAT—in a machine-learning algorithm, Bourgeau-Chavez creates maps that are four- to 30-fold improvements upon existing maps.

The improved maps show that, in Ecuador, half the landscape or more is peatlands, a significant increase over the Ecuadorian government's estimates.

Bourgeau-Chavez confirms what a difference mapping has made to wetland management: "This was the first time someone has mapped the peatland alpine regions," she says, noting that seasonal moisture patterns add complexities to the mapping. "In Ecuador, even the non-peatland areas are wet. If this mapping process works in Ecuador, it'll work anywhere."

"IF YOU TAKE CARE OF THE PEATLANDS, NOT ONLY DO YOU HAVE CLEAN WATER, YOU'RE STORING MOST OF THE CARBON IN THE COUNTRY. IF YOU MANAGE CARBON, YOU'RE MANAGING EVERYTHING ELSE."
—ROD CHIMNER

Bourgeau-Chavez is beginning to map Peru next, but her efforts are not confined to the Andes. SWAMP is an exercise in collaborative science between researchers, governments, and people, with benefits, insights, and spatial management data shared across borders and continents.

"Now that the methods are developed, we are seeking to apply them in the US," says Erik Lilleskov, research ecologist at the USFS's Northern Research Station in Houghton, Michigan. "It's a real positive for the USFS, because a lot of the federal lands in the American Rockies are high-elevation mountain peatlands as well."

MITIGATING

Mitigating the effects of climate change will require concerted, multinational efforts, so SWAMP emphasizes capacity building for local communities where the team samples.

"We're training people to do leading-edge science in these countries to aid in their ability to manage these ecosystems more effectively," Lilleskov says. "To the extent we can help other countries stabilize their environment, that allows them to thrive, and to be better partners of the US and the global community."

SWAMP projects include workshops with local universities, government agencies, and nongovernmental organizations on how to core peat, measure carbon and methane emissions using trace gas and eddy flux measurements, quantify carbon stocks, and wetland ecology basics. Chimner takes people into the field to demonstrate how to build check dams to restore damaged wetlands and works with ranchers to adopt more sustainable grazing practices.

"We're teaching them how to do this, so eventually they'll take it over completely," Chimner says, adding that several Ecuadorian and Peruvian students have completed graduate studies at Michigan Tech with the goal of taking their knowledge back to improve Andean peatland management.

RADIOCARBON DATING

Radiocarbon dating allows scientists to determine the time period during which peatlands were established in a particular area, how quickly the peat has been accumulating, and if there is loss of peat associated with historical and contemporary disturbances.

Kate Heckman, Radiocarbon Collaborative administrator at the Northern Institute for Applied Climate Science, supervises the preparation of samples for radiocarbon dating.

"As all living things do, the peat samples submitted to our lab contain a variety of elements, including nitrogen, oxygen, carbon, and hydrogen, among others," Heckman says, explaining a process called graphitization extracts and isolates individual carbon atoms.

Radiocarbon dating only reveals the relative abundance of radiocarbon in a particular peat sample, which allows scientists to calculate a calendar date associated with the creation of the peat. The environmental context, cross validation, and the knowledge of the scientist is then needed to interpret what this date means.

The Radiocarbon Collaborative is jointly supported by the USFS, the W.M. Keck Carbon Cycle Accelerator Mass Spectrometer Facility at University of California, Irvine, and Michigan Tech to advance climate and carbon science by making radiocarbon analysis accessible, decipherable, and collaborative.

>>>Get a behind-the-scenes tour of the Radiocarbon Collaborative: mtu.edu/news/radiocarbon

SLEEP LAB GETS TO THE HEART OF THE MATTER

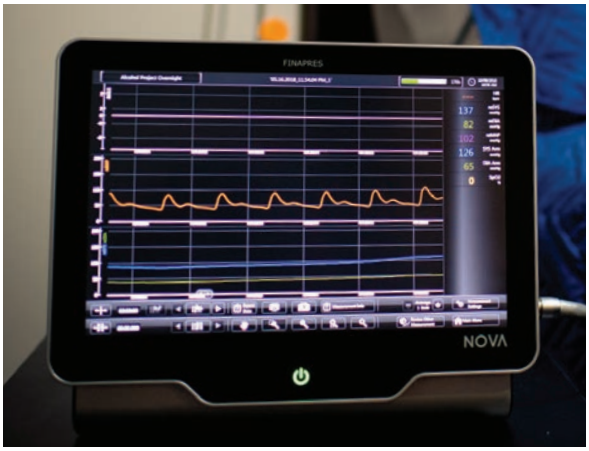
Using novel combinations of advanced technologies to understand sleep and cardiovascular health.

Like death and taxes, another certainty for most Americans is lack of sleep. But what does sleep loss do to our bodies? What happens when we factor sex differences or alcohol into the mix?

The recently opened Michigan Tech Sleep Research Laboratory aims to answer those questions by combining sleep analysis technologies to provide a window into the effects of sleep on people in different stages of life.

The two-bed sleep facility is located in the Student Development Complex and has a core staff of two faculty researchers, a sleep physician, a registered nurse who is also a certified sleep technician, a lead doctoral student researcher, as well as graduate and undergraduate students.

Studies at the facility hinge on research into the effects of sleep on cardiovascular health, contributing to the broader field of sleep research—a field that is growing rapidly.



Beat-to-beat assessment of blood pressure throughout the night is a key marker of cardiovascular health.

"What implication does sleep have? We sleep one-third of our lives. It's a huge chunk of our days," says Jason Carter, associate vice president for research development and professor of kinesiology and integrative physiology. "An elephant only sleeps three hours a day, while a lion sleeps up to 20 hours day. We see huge species variation in sleep, but we still don't fully understand what sleep does."

GOOD NIGHT, SLEEP TIGHT

When people check into the new sleep research laboratory, they find their schedules are packed, which is perhaps surprising considering the focus of the session is a good night's sleep.

Upon arriving at 4:30 PM, a participant in the National Institutes of Health-funded "Alcohol and Neurovascular Control in Humans" study undergoes numerous measurements, including arterial stiffness, baseline alcohol intake test, urine test, and blood draws. After a standardized dinner followed by a sleep questionnaire, the participant has about 30 minutes of rest while lying down—just in time for *Jeopardy!*—followed by blood pressure measurements and a psychomotor evaluation. Researchers then simulate a binge-drinking episode by providing three alcoholic drinks before a Brief Biphasic Alcohol Effects Scale (B-BAES test, which measures alcohol's acute stimulant and sedative effects on the participants, followed by three more alcoholic drinks. The time is now 9:15 PM and the participant is hooked up to the polysomnography equipment that measures brain waves, blood oxygen levels, heart rate, and breathing, as well as eye and leg movements. The sleep study continues with three more B-BAES tests staggered every 15 minutes along with what amounts to a more detailed drunk driving test—blood draw, questionnaire, psychomotor evaluation. Four more B-BAES tests every 15 minutes, and it's lights out at 11 PM.

Both of the sleep rooms in the new facility not only have the capabilities of the overnight polysomnography, but also take simultaneous measurements of beat-by-beat blood pressure: finger plethysmography, which constantly records blood pressure throughout the night; pulse oximetry, which measures oxygen content in the blood throughout the night; and transcutaneous carbon dioxide levels from the skin.

DREAMS AND DATASETS

The Michigan Tech facility meets all of the physical requirements to seek a sleep study center accreditation from the American Academy of Sleep Medicine. Additionally, researchers are working with sleep study software company Natus to add blood pressure readings to the data. The team's interdisciplinary, big data approach to sleep research includes biomedical engineering signal processing techniques applied to physiology.

"We're using these technologies in novel combinations to better understand the impact of things like alcohol, sleep deprivation, and insomnia on blood pressure," Carter says. "There's a complex relationship between sleep and blood pressure control. The epidemiological evidence is clear that these are strongly coupled."

The amplification box has 32 channels that include input of brain wave signals.

Nasal cannula and EMG electrodes track airflow and ocular and chin movements to complement brain wave signals.

The respiratory belt measures respiration and height correction unit for blood pressure.

Continuous monitoring of blood pressure throughout sleep is possible through finger plethysmography.

The pulse oximeter measures oxygen saturation.

TRACKING ZZZS

Both of the rooms of the new sleep research lab are outfitted with numerous technologies that, coupled together, provide the datasets necessary to analyze what makes for a good—or poor—night's sleep. Blood oxygenation levels, blood pressure, and sleep cycles are just a few of the nearly two dozen signals the researchers track.

Carter and his team are using the vast datasets collected during a night of sleep and analyzing them with advanced analytics to answer questions that were never possible before. "We characterize based on what's happening during different stages of sleep," he explains, "based on the physiological differences between men and women, and based on whether insomnia is a factor, to help guide therapeutic strategies and interventions."

"WE TALK ABOUT EXERCISE AND EATING RIGHT, BUT WE ALSO NEED TO FOCUS ON HOW IMPORTANT SLEEP IS. IT'S LIKE BRAGGING ABOUT HOW MANY STEPS YOU WALKED IN A DAY. WE NEED TO SWITCH THE FOCUS TO TELLING PEOPLE HOW MUCH SLEEP WE GOT, NOT HOW LITTLE."
—ANNE TIKKANEN

During the night, the Michigan Tech sleep research lab staff monitor a participant's sleep to watch in real time as the data is collected.

"People say that sounds like such a boring job. It's not," says Anne Tikkanen, registered nurse and the lab's lead sleep technician. "We have 20 signals going across the screen—we can see the stages of sleep and watch them change. Once you unhook the study participant in the morning, those signals are gone. Each signal has to be clean, so you have to stay on top of it during the night. If a sensor falls off, you ask yourself, how important is it to the analysis?"

Ian Greenlund, doctoral student in the sleep research laboratory, says sleep apnea events are a common observation during a session.

"Some people can stop breathing for up to 20 to 40 seconds during an apnea," he says. "You find yourself staring at the screen saying, 'Breathe!'"

But study participants can rest assured, "We are closely watching in case we need to intervene. Apneas are a common occurrence throughout the night, but various conditions can increase their number and severity, including obesity," Greenlund says. Obesity leads to obstructive sleep apnea—the excess tissue blocks airways, and when you bring in binge drinking, it makes apneas worse.

HEARTFELT SLEEP

Humans are most at risk for heart attacks between 6 AM and noon. And a good night of sleep may matter more for women than men.

Greenlund notes that blood pressure typically dips 10 to 15 percent during the night, and in people with hypertension, obstructive sleep apnea, and insomnia, there's an exaggerated surge of blood pressure in the morning, potentially leading to cardiovascular events.

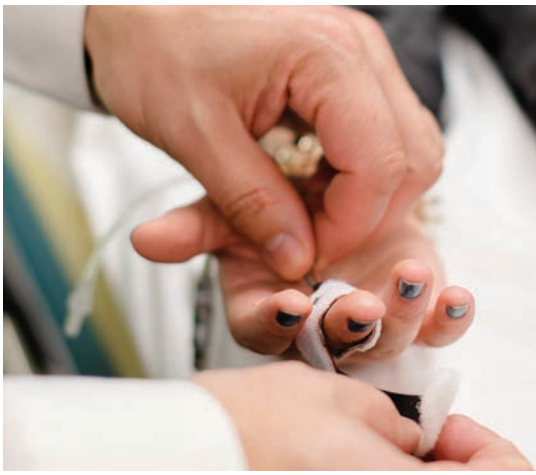
At 7 AM, the sleep study participant is unhooked from the polysomnography machine, and their urine is tested for hydration status. Researchers conduct an alcohol intake test post-sleep to further understand how the body processes alcohol during sleep, and follow that with blood pressure and blood draws.

"We know men and women don't metabolize alcohol the same way or at the same speed," Carter says. "We believe there are some important differences in evening alcohol consumption, particularly binge alcohol consumption, on sleep and on risk throughout the night and the following morning."

After another affective questionnaire and psychomotor evaluation, the researchers begin microneurography at 8:15 AM, which measures cardiovascular risks: blood pressure, heart rate, nerve activity, respiration rate. Carter likens the stress of the human sympathetic nervous system—the so-called fight-or-flight response—to revving an engine to redline. The team puts study participants through stress tests in the lab's safe and controlled environment.

They mimic everyday stressors like shoveling snow by having the person put their hand in a bucket of icy water to simulate thermal stress and raise blood pressure. Does the sympathetic nervous system surge after a binge-drinking episode? Does dehydration factor in? The ultimate goal

Tiny sensors embedded in a finger cuff allow for continuous monitoring of blood pressure.



is to understand the combined effects of alcohol on sleep and cardiovascular risk as well as compare the physiological effects on men versus women.

EVERYBODY NAP NOW

Population-based data suggests certain cardiovascular diseases like hypertension are more strongly associated with short sleep in women than they are in men. The sympathetic nervous system's reaction to sleep deprivation is more pronounced in women.

"When women are deprived of sleep, their nervous systems appear to respond more aggressively than men," Carter says. "There's an acceleration of the nervous system. We see higher blood pressures and greater potential risk for heart attack. The surge of sympathetic activity also increases the risk of stroke. Too much of an excitation of the body sets a person up for negative cardiovascular events acutely and chronically."

The sleep research lab also recently completed a study into the effects of menopause on sleep. Carter says that sympathetic nervous system excitation was even more dramatic in post-menopausal women than in younger women.

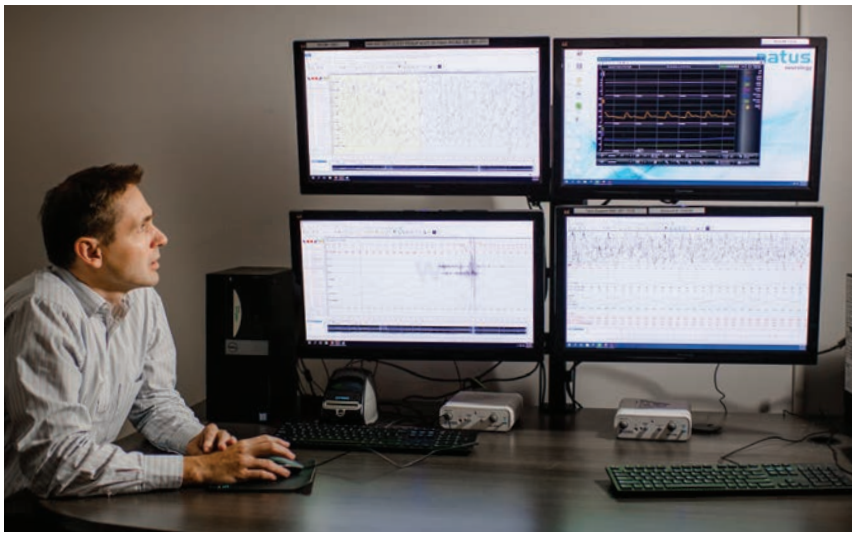
"We tend to see overactivity of the nervous system across the lifespan of women—and the cumulative effects of sleep deprivation could be a key contributor to hypertension," he says. "When women hit menopause, their risk factors for hypertension exceed that of older men."

Carter notes that women tend to be "cardio-protected" in early life compared to men, but that women lose such protections when their hormonal levels change during menopause, which seems to accelerate other risk factors.

But getting a better night's sleep consistently isn't just recommended for post-menopausal women. Sleep researchers hope to see wholescale societal shifts toward valuing sleep more—and at the college level as well. College students are chronically sleep deprived, and what sleep they do get is often low quality. Combined with the stresses of school, unhealthy diet, or drinking choices, the consequences can be life altering.

Carter says that lack of sleep is ultimately as detrimental on health as being overweight or smoking. "Sleep deprivation slowly accumulates into major health problems," he says. "We use advanced technologies to answer questions that lead to better quality of life. When you're sleep deprived it affects your mood, it affects everything about you."

During deep sleep cycles, the brain's production of growth hormone surges, healing the body. During the rapid eye movement (REM) cycle, memories solidify. There's also evidence that REM sleep reduces risk of dementia and Alzheimer's disease. Carter advocates for napping because the total amount of sleep a person gets doesn't necessarily need to be consolidated into an uninterrupted eight hours. Depending on your body's needs, 30 to 90 minutes is the ideal amount of time for an afternoon siesta. If you wake up groggy, you've napped too long.



▲ Jason Carter examines brain waves and blood pressure simultaneously recorded throughout the night.

"There's a reason from a physiological perspective people take naps around 2 to 3 in the afternoon," he says. "We can get a tremendous amount of restorative sleep during a nap. I think naps represent a strong countermeasure to consequences of short sleep."

Whether it's a full night's rest or a good nap, Carter wants everyone to wake up to the need for good sleep.

"We have the ability to combine various advanced technologies to drive creative interventions and make up for chronic sleep deprivation in today's society," Carter says. "The real-world applicability and emphasis of our research is to ultimately inform and educate the public on how we might avoid or slow down the risk for cardiovascular disease as it pertains to sleep insufficiencies."

A BATTERY'S GUIDE TO IMMORTALITY

Born again and again and again. Two engineers and their students look at how to reincarnate lithium-ion batteries.

Nearly all lithium-ion batteries live once and die. Those that power our cell phones can be charged hundreds of times, and when they fail, we can recycle them (or, many times, chuck them in the trash).

Not so with the big batteries in electric vehicles (EVs). "They can have two lives," says Lucia Gauchia, assistant professor of mechanical engineering as well as electrical and computer engineering. "The first life is in our vehicle, but that only lasts until the battery is 20 percent dead."

Being 80 percent alive isn't good enough for an EV, but it's fine for storing power as part of a home photovoltaic system or electrical grid. But how fine is it really? Just as there's a bit of mystery to buying a used car, it's hard to know what you're getting when you repurpose an old lithium-ion battery.

"Because of the way batteries age, it's difficult to understand how its first life will affect its second life," Gauchia says. "How damaged is it? How does the customer know it's a good, safe product?"

Lucia Gauchia studies the second lives of batteries.

KICKING THE TIRES ISN'T ENOUGH

Sure, you can check an EV battery's age and mileage, but those are only approximate measures. "Aging depends on how you use it," she says. "It depends on a lot of different variables, like driver behavior, temperature, and driving conditions." In other words, batteries that aren't taken care of won't last as long as the ones that amble back and forth to the grocery store.

And while engineers are comfortable evaluating the condition of bridges, batteries are another matter. "The funny thing is, people in engineering aren't used to our systems aging so fast," Gauchia explains. "The aging behavior of batteries is a lot more dramatic than other systems."

HOW IS A BATTERY LIKE A FISH?

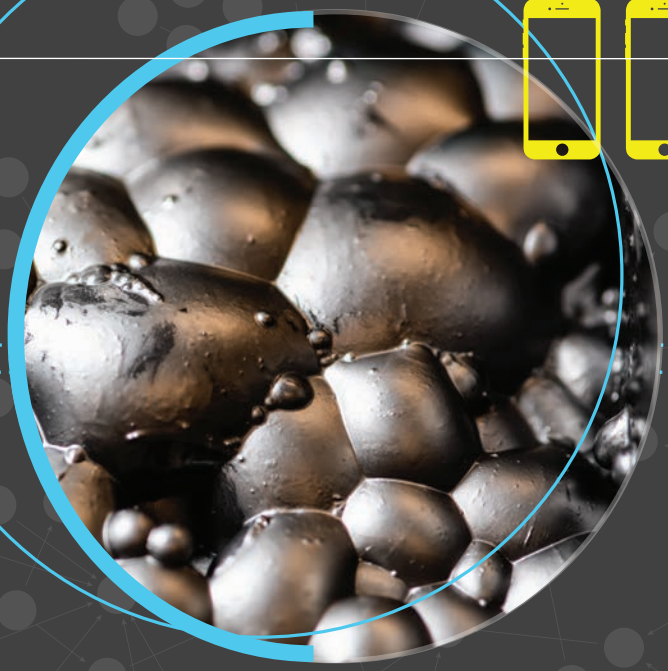
A couple of years ago, when Gauchia was trying to design a study to predict how batteries age, she realized that she needed to stop thinking only in terms of the battery itself and start looking at its environment. What she needed was to study batteries the way scientists study living things. Like fish.

Fish biologists predict whether they will survive and thrive under a staggering variety of conditions: differing water temperatures, pollutant levels, food availability, predator and competitor populations, oxygen concentrations, etc. To find out how scientists study fish, she reasoned, read the fisheries journals.

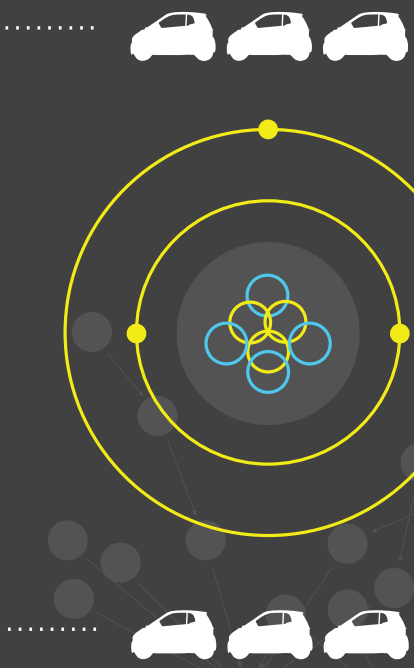
"That's when I saw that a lot of the studies use Bayesian statistics," she says. "I went, 'Maybe I should turn Bayesian.' That was an a-ha moment."

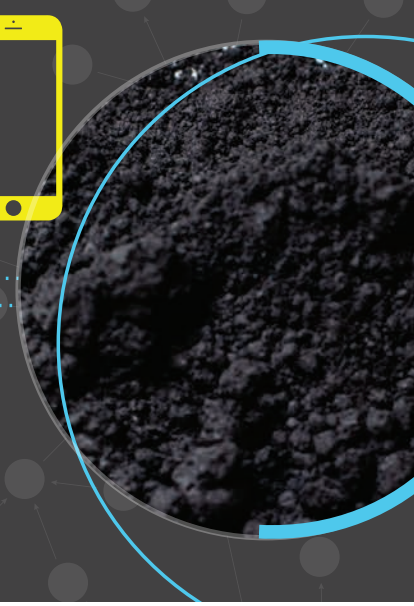
THE TRUTH, THE WHOLE TRUTH, AND BAYESIAN STATISTICS

Bayesian statistics incorporate probability and is a standard tool for weighing the effects of multiple environmental variables. Inspired, Gauchia took her cue from ecological Bayesian models, except instead of trying to decide whether to stock a lake with walleye, she aims to predict how long batteries will have useful first and second lives.



Battery materials: silver graphite bubbles and black lithium oxide powder.





The experiment began last fall, with Gauchia and her students writing reams of code to create a computer model of a battery's two lives, including the conditions that it's likely to face and the probability that those conditions will occur.

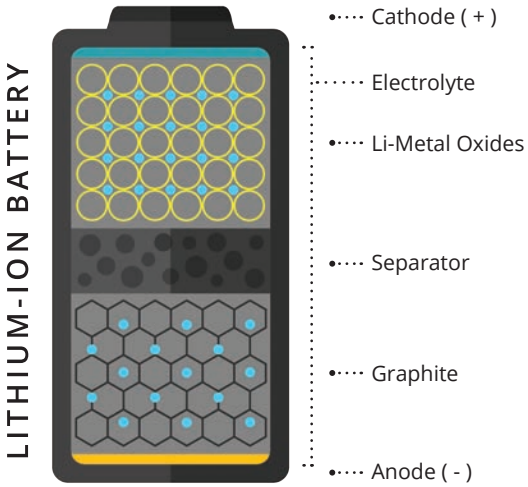
"Then every day, I sample those probabilities to decide what the battery will do that day, and I download that profile into my test system," an array of about 100 battery cells, all wired up to charge and discharge at the direction of the computer.

The model replicates how a battery might run any day of the year, from first-life driving conditions to the demands of its second life, when homeowners will be doing laundry, turning on electric heaters, powering up the air conditioning, and maybe selling their excess electricity back to the power company. Yes, she admits, it is complicated.

The research is funded by a National Science Foundation (NSF) Faculty Early Career Development (CAREER) Award and also includes an educational component: a lab specifically for students, which will complement the work being done in her research lab. In addition, Gauchia, a native of Spain, has reached out to students—Latina women in particular—at Grand Rapids Community College to encourage them to participate in the study and gain research experience.

Gauchia will use her results to fine-tune the team's original models. "When we are done,

Students help Gauchia and Pan study battery reincarnation.



I hope to propose new management algorithms for batteries that will improve forecasts of their use," Gauchia says. "We want to figure out how to give them a longer life, first in EVs and then in their second life, before they have to be recycled."

BEYOND THE AFTERLIFE

When a battery dies for good, recycling is the most sustainable option. But while nearly all old-style automotive batteries are recycled, that's not the case with their lithium-ion counterparts.

"There is no plant in the US for recycling lithium-ion batteries," says Lei Pan, assistant professor of chemical engineering. That's because there's no economically viable recycling program, and federal law does not mandate the recycling of spent lithium-ion cells. As a result, people usually just toss them into the garbage. Nevertheless, lithium-ion batteries can be highly problematic in landfills. They contain trace amounts of toxic chemicals, and unless they are fully discharged, batteries have an alarming tendency to catch fire and blow up.

SOMETHING OLD FOR SOMETHING NEW

The main stumbling block for recycling lithium-ion batteries is that the two conventional recovery technologies are expensive, says Pan. In pyrometallurgy, the most valuable materials, copper and cobalt, are melted and converted into an alloy, which is processed to make the raw materials for new batteries. The second process, called hydrometallurgy, uses acid to leach metals into solution and convert them to salts, which must be processed into new materials before becoming the feedstock for new batteries.

"Those processes convert the material you want into something else and then back into what you want," Pan says. "That's a waste of energy." Federal agencies are asking the research community to try a different approach: separating materials in the batteries without changing their chemistry. If it were easy, someone would have done it already.

"There are a lot of challenges," Pan says. "You have to make sure the battery components remain intact during the recycling process. You have to separate each component—there are a lot of components—and make sure the purity of each is 95 percent or higher." Finally, you need a commercial infrastructure to make it all work. As Pan notes, "Somebody has to actually use it," and it needs a track record.

Though Pan is in the chemical engineering department, his graduate degrees are in mining engineering. He figured the same technologies to separate valuable minerals from ore could be applied to separating 21st century battery components. So, he assembled a team of students, gave them a crash course in basic minerals processing methods, and set them loose in the lab.

STEP 1: FIND THE BATTERIES

The crew needed to get their hands on a bunch of spent lithium-ion batteries. They found several willing donors, including Michigan Tech's Office of Information Technology, the Marquette County Solid Waste Management Authority, and the owners of various old laptops and consumer electronics. Then, the team discharged the batteries and opened them all manually, removing the plastic casings to obtain more than 100 cells.

STEP 2: BREAK EVERYTHING APART

They shredded the batteries' copper and aluminum conductors, then pulverized the anodes and cathodes to dust before blending the whole mix in water to create a slurry. Their challenge was then to separate out each of the original components—especially the high-value cathode, which often includes cobalt as well as lithium.

"My mind goes back to the beginning, when nothing was working," says team member and soon-to-be graduate Trevyn Payne. Fellow chemical engineering student Zachary Oldenburg provides an example. "We were trying all kinds of solvents to liberate chemicals, and after hours and hours, we found out that plain water worked the best."

Eventually everything came together. "You can see your results improve experiment by experiment," doctoral chemical engineering student Ruiting Zhan says. "That's pretty good. It gives you a sense of achievement."

STEP 3: SORT THE MATERIALS

The students developed two separation techniques designed to form the heart of a commercial recycling process. To retrieve the aluminum and copper bits, they ran the slurry through a screen. That left them with a mix of coarsely shredded metals. To sort them, the team used the ancient technique of gravity separation, relying on typical industry tools: a shaker table, a teeter-bed separator, and a spiral separator. Like a miner panning for gold, the machines isolate materials by density, sorting them into near-pure copper, aluminum, lithium-metal oxide, and graphite.

Separating the dust from the anodes and cathodes was more complicated. The team used a technique called froth flotation, which relies on materials' different affinities for water. Air is bubbled through a solution containing the particles, collecting those that are hydrophobic in a froth at the surface, where it can be skimmed off. In this case, the graphite from the anodes floated in the froth, while the valuable cathode material sank to the bottom.

STEP 4: PUT THEM BACK TOGETHER AGAIN

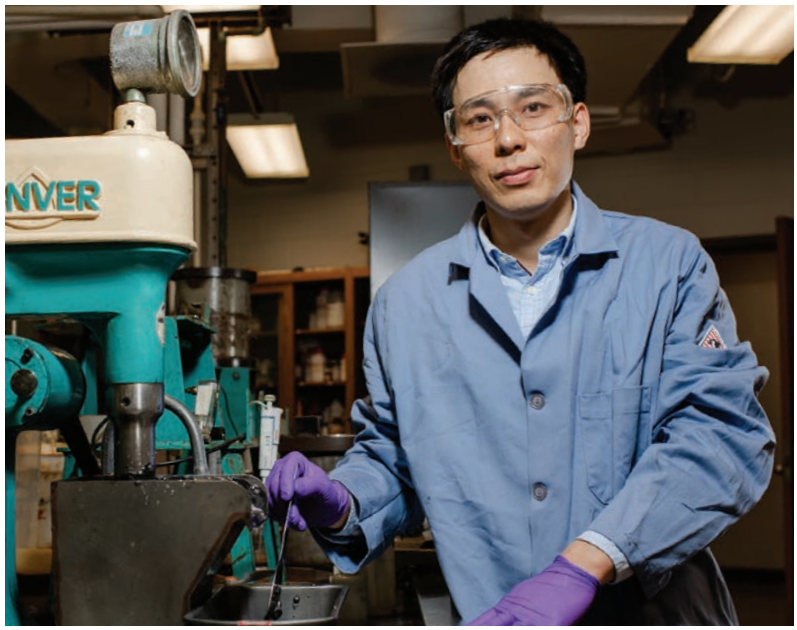
The students were able to recover approximately 75-90 percent of the cathode material and verify its purity at more than 95 percent. To put it to a real-world test, they made a working battery from the isolate. The results were gratifying. "For the purpose of remanufacturing, our recycled materials are as good as virgin materials, and they are cheaper," says Oldenburg.

They also did an economic analysis comparing their methods with the standard pyrometallurgy and hydrometallurgy techniques. The bottom line: Their process yielded more valuable materials at a lower cost. "The biggest advantages of our process are that it's very inexpensive and very energy efficient," Pan says.

Their work caught the eye of the American Institute of Chemical Engineers (AIChE), which gave the team its 2018 Youth Council on Sustainable Science and Technology P3 Award. They were invited to give an oral presentation on their process at AIChE's Annual Meeting in Pittsburgh last fall, with AIChE covering their travel expenses.

WHAT'S NEXT: PROOF OF CONCEPT

With funding from the Michigan Tech Translational Research and Commercialization (MTRAC) Statewide Innovation Hub, the Environmental Protection Agency, and an Innovation Corps grant from the NSF, Pan is working toward making a bench-scale, battery-recycling plant that can be operated continuously. It will start by crushing whole batteries and add steps to separate out all the materials, including plastics and steel casings. When they are sorted and cleaned, the components can be remade into new batteries or recycled for other uses.

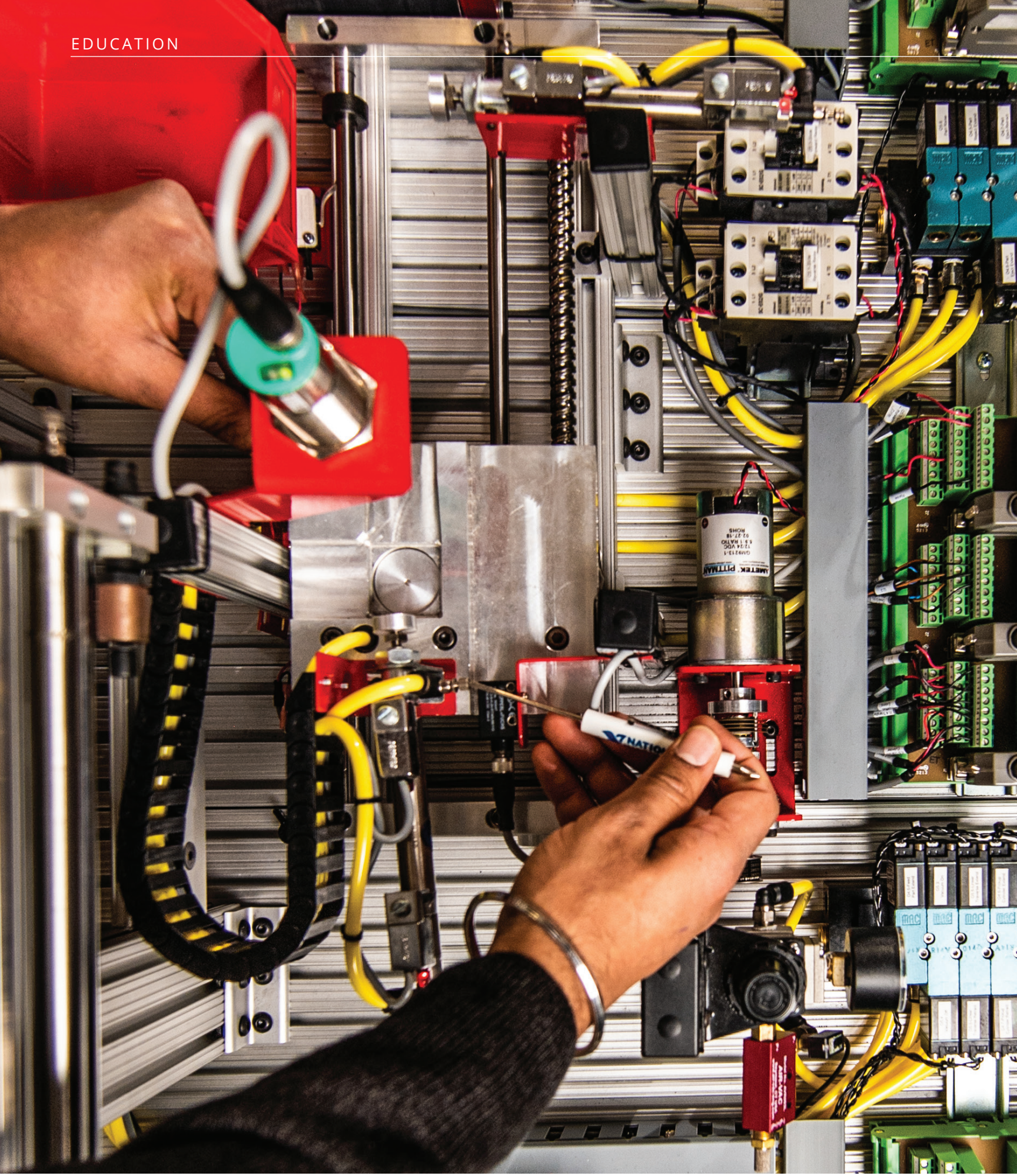


Inspired by mining, Lei Pan extracts battery components.

"A similar process has been used to recycle lead automotive batteries for about a hundred years," Pan says. More than 99 percent of lead batteries are recycled, according to Battery Council International, and the average lead battery is made of more than 80 percent recycled material, from lead and plastic to sulfuric acid. The near-perfect recycling rate comes from industry investment in a system that keeps 1.7 million tons of batteries out of landfills each year.

"We are applying the same model to the lithium-ion battery," Pan says. "The idea is simple. It's just a matter of making sure everything works."

And they hope to make it work on a national scale. Pan is one of the researchers involved with the new Battery Recycling R&D Center, an initiative funded by the US Department of Energy and led by Argonne National Laboratory. From cobalt to lithium, they plan to make reclaiming battery materials as common as lead.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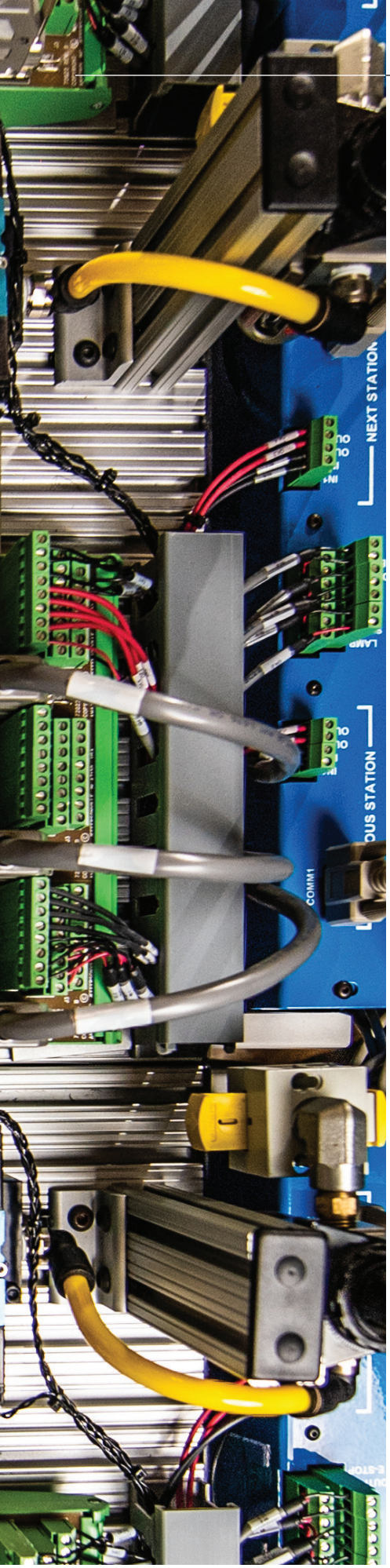


All in, hands on. Mechatronics students precisely tune intricate electro-mechanical systems.

EDUCATION ECOSYSTEM FOR STEM

Science, technology, engineering, and math are not verbs. But putting STEM—a blend of all four concepts—into action is the best way to help students learn.

Pedagogy, the science of teaching, keeps educators on their toes. They are challenged to create exciting, relevant, and comprehensive environments that promote active, practical learning—preparing people for future jobs and communities.

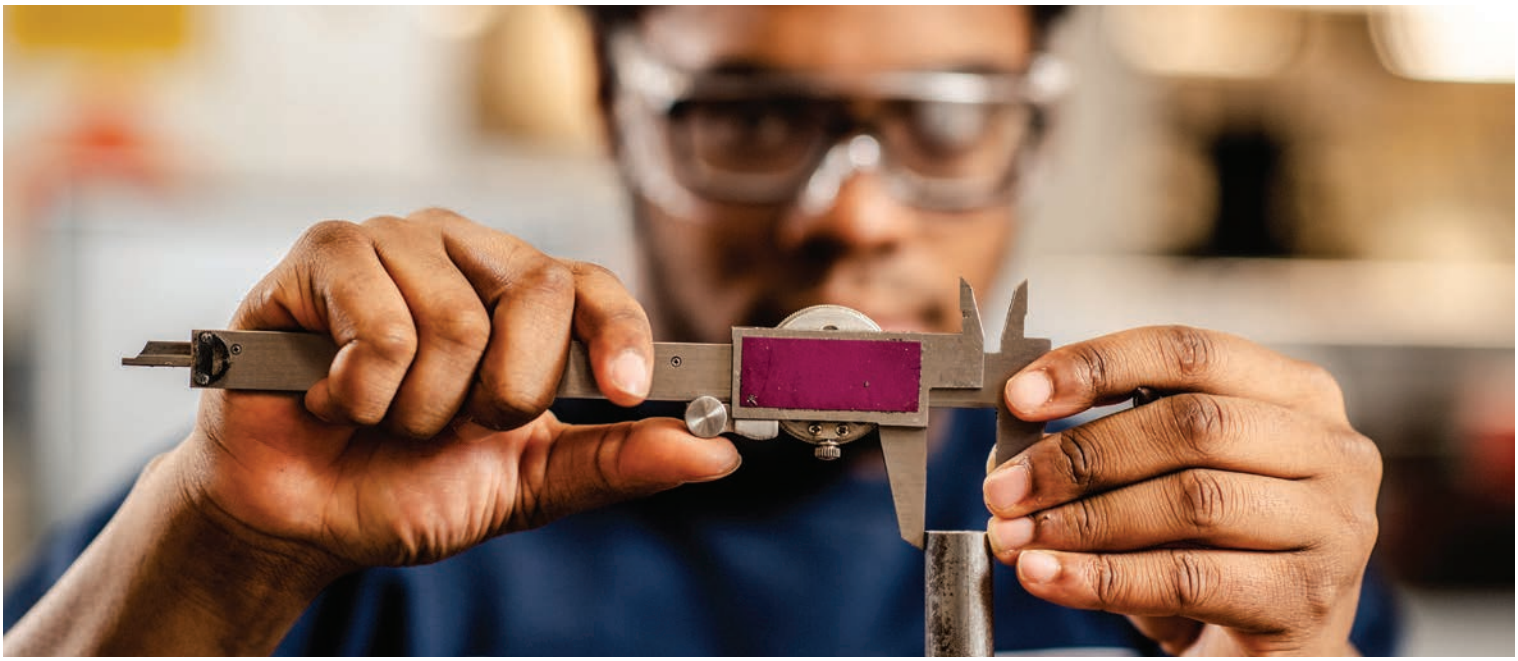
Which is greatly needed: By 2020, one in five jobs in the state will be STEM-related, reports the State of Michigan Bureau of Labor Market and Strategic Initiatives, which also projects that STEM job opportunities will grow by 11.8 percent, outpacing the expected 8.5 percent increase in other occupations.

Three Michigan Tech initiatives, Mi-STAR, ETS-IMPRESS, and mechatronics, address specific, high-priority state and national goals to improve STEM education. The programs are designed to be affordable, inclusive, and to address career needs for individuals and industry.

Each initiative is an ecosystem—a space full of life, ready to change and evolve. And like a forest, desert, or coral reef, each ecosystem's growth is shaped greatly by its substrate. These educational ecosystems are nourished by good mentors, who are committed to fostering resilient learners able to weather the storms they will encounter throughout their lives and careers. Looking deeper into these Michigan Tech programs reveals the interconnectedness and organic circuitry that fosters healthy educational environments.

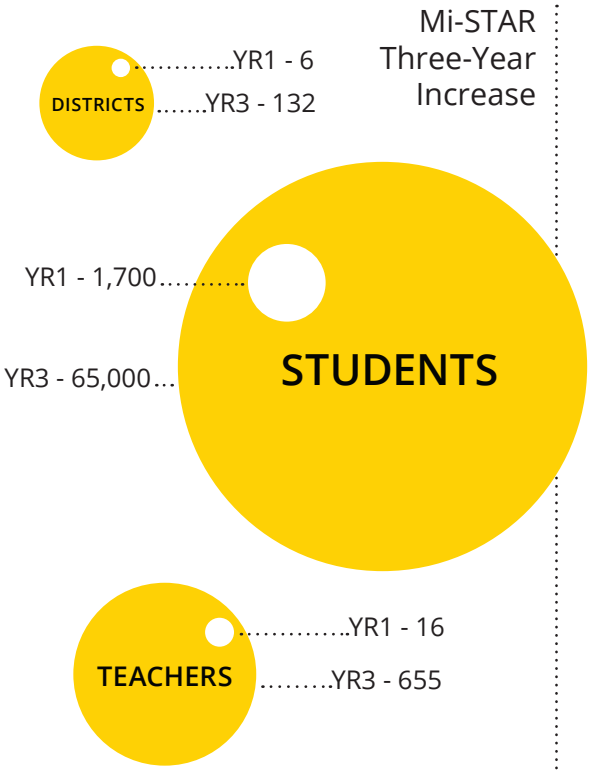
MIDDLE SCHOOL

Mi-STAR is the Michigan Science Teaching and Assessment Reform. Within a Mi-STAR middle school classroom, it's readily apparent something is different. Lectures are few and far between; student team projects range from making a smoothie to treat a digestive issue to pouring glasses of water on toy towns to study flooding. The program's relatable curriculum, which integrates science and engineering, sets it apart.



Michigan Tech programs build connections between schools, community partners, and industries.

Started in 2015, the program has grown exponentially from six school districts reaching 1,700 students and 16 teachers, to 132 districts, 65,000 students, and 655 teachers. Mi-STAR aspires to provide a full middle-school curriculum for Michigan schools in the near future that aligns with the Next Generation Science Standards (NGSS) for K-12 education.



Initially funded by the Herbert H. and Grace A. Dow Foundation, Mi-STAR received new support from the National Science Foundation (NSF) and the State of Michigan last year. Barb McIntyre, retired Midland Public Schools teacher, says: "This has got to be one of the most important things the Herbert H. and Grace A. Dow Foundation has ever funded. The difference this has made for underserved students in terms of growth and improved performance is phenomenal."

Jackie Huntoon, Michigan Tech provost and senior vice president for academic affairs and an inaugural member of the Federal STEM Education Advisory Panel, helps guide Mi-STAR. "Teaching with Mi-STAR can be challenging at first, because teachers have to give students control of the learning process," Huntoon says, adding that with practice, teachers see changes. "Kids who used to sullenly drag themselves into science class are now eager for class to begin. All students have something valuable to contribute. We know Mi-STAR is making a difference for them."

"WE NEED TO ADDRESS REAL-WORLD PROBLEMS THAT ARE OF WIDE INTEREST TO 21ST-CENTURY SOCIETY."
—JACKIE HUNTOON

And for their teachers. Professional development and support are key parts of Mi-STAR. Emily Gochis, Western Upper Peninsula regional director for the MiSTEM Network, based out of the Copper Country Intermediate School District, and a Michigan Tech doctoral student in geoscience, has been with Mi-STAR since the beginning.

"Things are always changing, especially in science," Gochis says. "There's new information constantly coming out. Science teachers are challenged in a lot of ways; Mi-STAR empowers them."

PREPARING FOR CAREERS

ETS-IMPRESS is Engineering Technology Scholars IMProving Retention and Student Success. It picks up where Mi-STAR and K-12 education leave off; students in the program work on cultivating their engineering careers, no matter their background.

"Our overall goal is to increase student retention and graduation in technology fields, which are vital to the regional and US economy," says Nasser Alaraje, professor and program chair of the electrical engineering technology program and principal investigator for the project. "In partnership with Michigan Tech's Pavlis Honors College, ETS-IMPRESS fosters leadership, technical know-how, and employability skills for technology fields that actively recruit and employ graduates from diverse backgrounds and communities."

Funded by the NSF for five years, the project will award 12 first-time undergraduate engineering technology students with four-year scholarships and 36 community college transfer students from Michigan and neighboring states with two-year scholarships of $4,500 per year. ETS-IMPRESS' research component investigates how a structured support program influences transfer student performance, retention, and time to graduation.

MAKING CONNECTIONS

Mechatronics is a combination of disciplines—mechanical, electrical, computer, and systems engineering, along with telecommunications, robotics, automation, and controls. To bring mechatronics to the classroom, Michigan Tech is partnering with Bay de Noc Community College with funding from the NSF, US Department of Labor, state agencies, and industry. Aleksandr Sergeyev, professor of electrical and computer engineering, is leading the initiative.

"Our program uses complementary, open-source robotics software to teach a general robotics curriculum," Sergeyev says. Teaching robotics normally requires expensive hardware, so to bring the cost down, Sergeyev tapped the expertise of Scott Kuhl, associate professor of computer science. Kuhl, together with Michigan Tech undergraduate computer science students, designed RunRobot, a free program available on GitHub.

"We wanted to know if it was possible to write a program that was not necessarily as complete as a software package you'd buy, but with enough to help people trying to learn the basics," Kuhl says.

To some extent, the limitations, namely a lack of specific production features, are an advantage, Sergeyev says, because training only uses 10-15 percent of complex, pricey software. Through RunRobot, inexperienced users can learn to control a robot in a simulated environment, including operating, programming, and object recognition using image processing.

ECOSYSTEMS

The routes into STEM are often nonlinear. While Michigan Tech's new and existing STEM programs are already expanding opportunities across educational levels, there will always be room to grow.

With 655 teachers in training, Mi-STAR continues to serve more schools every year. Mechatronics hopes to grow into an interdisciplinary graduate degree program, addressing a need affirmed by Tesla, GM, Ford, FANUC, and Kaufman Engineered Systems, for midcareer engineers. And ETS-IMPRESS will welcome a new cohort—of many to come—later this year.

Each program is a microcosm of the greater changes happening within STEM education. Together, they demonstrate how Michigan Tech supports, challenges, and prepares students for social mobility.

>>>Learn more about ETS-Impress: mtu.edu/ets-impress

See unit lesson examples and follow the Mi-STAR blog: mi-star.mtu.edu

READY USER ONE

Reality might leave a lot to the imagination, but researchers at Michigan Tech are filling in the gaps.

While cranking out text is an integral part of our digital lives, it's a field of research missing in virtual reality (VR) and augmented reality (AR) development. Our computer scientists delve into the different ways to type in VR and AR spaces.

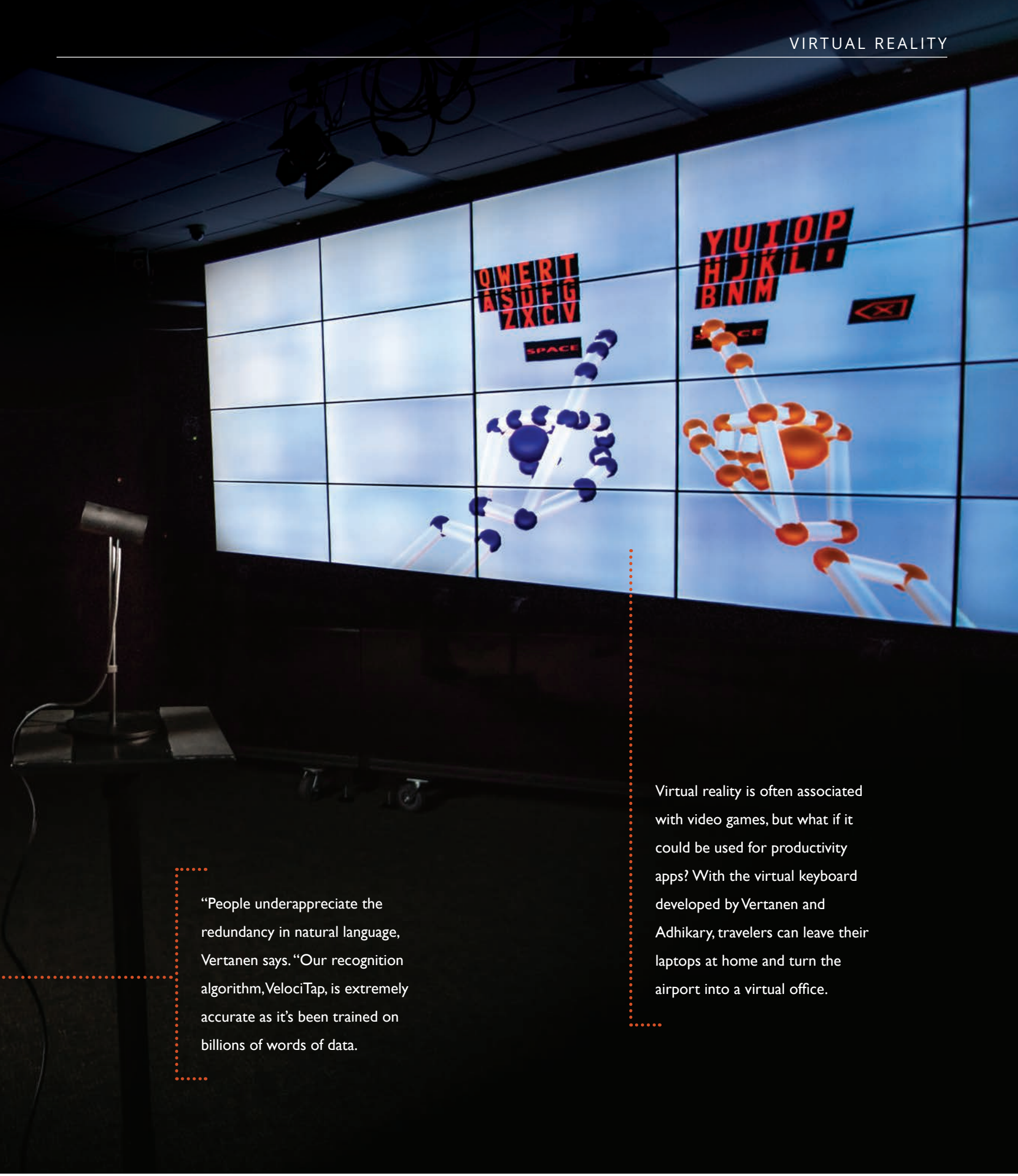
In VR worlds, the user's environment is entirely simulated, whether it be a video game, military exercise, or flight simulation. AR technology allows people to add digital content to their existing physical environment, from the simple (fun filters on Instagram) to the complex (helping surgeons perform complicated operations).

In both worlds, keyboards come in handy (pun intended). Keith Vertanen, assistant professor of computer science, and doctoral student Jiban Adhikary developed a mid-air virtual keyboard by mounting a hand-tracking device on a VR headset. The device senses the position of both hands and renders them in the virtual world. The user also sees a floating QWERTY keyboard.

Research from Scott Kuhl, associate professor of computer science, and James Walker, lecturer in computer science, allows the user to work on a physical keyboard while in VR. An image of the keyboard shows what keys have been typed, but the user doesn't see their hands.

Both programs use a powerful text recognition algorithm, VelociTap. "Think autocorrect on steroids," Vertanen says. "It can make sense of very 'noisy' data, so you don't have to always hit the correct key."

"Lots of people are buying head-mounted displays, but it's mostly for video games," Kuhl says. "We're figuring out how to use a head-mounted display for office work like writing and editing a document or sending a message to someone.



Virtual reality is often associated with video games, but what if it could be used for productivity apps? With the virtual keyboard developed by Vertanen and Adhikary, travelers can leave their laptops at home and turn the airport into a virtual office.

"People underappreciate the redundancy in natural language, Vertanen says. "Our recognition algorithm, VelociTap, is extremely accurate as it's been trained on billions of words of data.

Awards

NATIONAL SCIENCE FOUNDATION FACULTY CAREER AWARDS

Michigan Tech researchers earn awards that reflect their dedication and innovation.

KEITH VERTANEN

Assistant Professor, Computer Science

What I do: Develop desktop, mobile, and augmented reality interfaces for communication

Why I do it: Give a voice to those with speaking challenges

Project: "Technology Assisted Conversations"

mtu.news/2rINw4E

SUMIT PAUDYAL

Associate Professor, Electrical and Computer Engineering

What I do: Calculate energy use ebbs and flows to optimize load flexibility and distribution networks

Why I do it: Ensure people have electricity and make distributed energy a reality

Project: "Operation of Distribution Grids in the Context of High-Penetration Distributed Energy Resources and Flexible Loads"

mtu.news/2NGvrRz

YE SUN

Assistant Professor, Mechanical Engineering–Engineering Mechanics; Affiliated Assistant Professor, Biomedical Engineering

What I do: Build embroidered electronics to replace wearable health monitoring devices

Why I do it: Art and engineering meet in the stitches of electronic fabric to make health data more accessible

Project: "System-on-Cloth: A Cloud Manufacturing Framework for Embroidered Wearable Electronics"

mtu.news/2zHRGQx

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.

FENG ZHAO
Associate Professor,
Biomedical Engineering

ZICHEN QIAN
PhD Student,
Biomedical Engineering

What we do: Engineer soft tissues from naturally derived scaffolds and multi-potent adult stem cells

Why we do it: Help patients recover more quickly and effectively from burns and heart attacks

mtu.news/2rhURYJ

MICHIGAN TECH RESEARCH AWARD; ACCELERATE MICHIGAN UP AND COMER 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.

YOKE KHIN YAP
Professor,
Physics

What I do: Develop and commercialize functionalized boron nitride (BN) nanostructures

Why I do it: Precise medical diagnosis and quantum transistors for future electronics

mtu.news/2vRa7QT

ACCELERATE MICHIGAN INNOVATIVE COMPETITION GRAND PRIZE

L. BRAD KING
Ron and Elaine Starr
Professor in Space Systems,
Mechanical Engineering-
Engineering Mechanics

What I do: Propel the small satellite revolution with better data, lower costs, fewer launches

Why I do it: More than 9,000 satellites are set to launch in the next seven years, more than all satellites in human history

mtu.news/2NIodMU

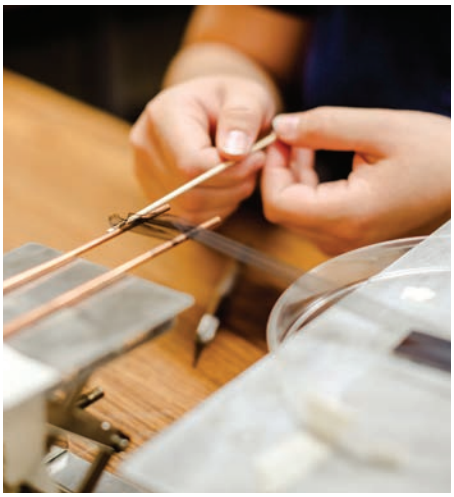
NATIONAL STEM EDUCATION ADVISORY PANEL APPOINTEE; GEORGE G. MALLINSON AWARD FOR LIFETIME ACHIEVEMENT IN THE FIELD OF SCIENCE EDUCATION

JACQUELINE HUNTOON
Provost and Senior
Vice President for
Academic Affairs

What I do: Advise a newly formed committee on best practices in STEM education

Why I do it: K-12 STEM education is vital to the nation; our students deserve a bright future

Beyond the Lab



Carbon nanotubes make heat-generated sound to cancel out the thrum of noisy industrial heating units in hospitals.

ALONG THE WILD SHORES OF LAKE SUPERIOR

Innovation is more than coming up with new ideas. It's making them happen.

Here's how we use our unique location in Michigan's remote Keweenaw Peninsula to push the boundaries of research: test winter tires on a specialized ice rink at the Keweenaw Research Center. 3D print adaptive aids for people with hand arthritis and share the open-source designs worldwide. Survey underwater infrastructure; sample the water above from a University research vessel. Build thermophones from carbon nanotubes—see the photo to the left—that can reduce noise from heating ducts and help reduce dust, while even smaller nanoparticles can sharpen medical imaging with high-brightness fluorophores. And more—nanosatellites, blood typing, meditation, cybersecurity.

Michigan Tech is at the confluence of these future-thinking projects and this remote, beautiful place. It spans many fields and fosters interdisciplinary teams in the effort to take ideas out of the lab, refine them, and bring them to market.

INNOVATION CENTER FOR ENTREPRENEURSHIP

A collaboration between the Pavlis Honors College, School of Business and Economics, and the Vice President for Research Office, the Innovation Center for Entrepreneurship (ICE) kicked off in 2015 to cultivate innovation and entrepreneurship on Michigan Tech's campus. Programs include the New Venture Pathway, National Science Foundation-sponsored Innovation Corps (I-Corps) business development program, The Alley campus makerspace, student Entrepreneurs Club (E-Club), and the ICE House residential learning community. ICE launched the Husky Innovate series—workshops and events that guide participants through key phases of innovation and startup business development.

Co-director Jim Baker, associate vice president for research administration, explains, "Whether someone plans to work for a new company or an old company, for their own small startup or a large established corporation, the foundations of an entrepreneurial mindset are universally valuable and there are resources within ICE and through our collaborators to develop it."

>>>Discover the campus entrepreneurial spirit: mtu.edu/honors/ice

Superior Ideas

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

>>>Check out more projects at: superiorideas.org

110 110 projects

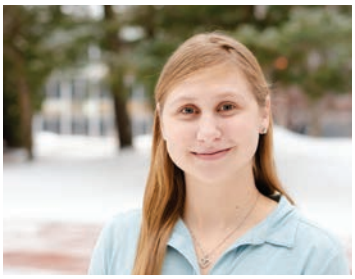
1518 1,518 donations

308K more than $308,000 raised

69K more than 69,530 unique users to the site

Student Research

UNDERGRADUATE STUDENT



Kaylee Meyers is a biomedical engineering student developing an in vitro model system to study the effects that extracellular matrix stiffness has on cells during acute and chronic injuries—integral for tendon and ligament healing.

Meyers is building on research she and her advisor, Rupak Rajachar, principal lecturer of biomedical engineering, did over the summer through a Portage Health Foundation Undergraduate Research Internship Program scholarship. She explains: "We're developing injectable hydrogels to accelerate wound healing in tendons and ligaments. Our hydrogels are unique because they not only reestablish extracellular matrix structure and function, but also have a controllable drug-releasing element."

Meyers started doing research the third month of her first year on campus. And she knew before Orientation Week that she wanted to do biomedical engineering research. She recalls, "I actually decided on pursuing biomedical engineering at Michigan Tech the summer after my junior year [of high school] when I attended the Women in Engineering Summer Youth Program."

Only in her second year, her sights are already set on graduate school. "I like learning new things," she says, "and I enjoy the research we are doing: the meaningful work, the challenging atmosphere, and the sense of belonging that the comradery of our lab creates." Meyers was accepted to present both an individual poster and oral presentation at the American Society for Matrix Biology Conference in October 2018. Before two days of presentations, Meyers competed in a half marathon. Despite long days spent in classes or the lab, her eyes light up when she talks about her vocation.

GRADUATE STUDENT

As a medical intern in Algeria in 2014, fourth-year biomedical engineering PhD student, **Maria Paula Kwesiga**, met a patient who changed her life. Complications from a prosthetic heart valve caused the patient's death; blood clots blocked a faulty heart valve. Kwesiga realized engineering could help improve current treatments for such pathologies. So she changed career paths and embraced two forms of frost: the Keweenaw and the personal (her graduate advisor is biomedical engineer Megan Frost). "I read about Frost's research in nitric oxide-releasing polymeric materials used for blood-contacting devices and how nitric oxide is involved in preventing the formation of blood clots," she says.

Kwesiga is the 2018 recipient of the Department of Biomedical Engineering Graduate Teaching Assistant of the Year award, vice president of the African Student Organization, and winner of presentation awards from the Upper Peninsula Local Section of the American Chemical Society, Michigan Physiological Society, and Michigan Tech's three-minute thesis competition. "I can't say enough good things about her." says Frost. "On all aspects of what a graduate student is intended to be doing, she's doing awesome."

In the lab, Kwesiga is building on Frost's research for clinical application in cardiology and skin-wound healing. She's also helping students learn experimental techniques, something she says she enjoys and would like to do after she graduates. "What drove me into coming to Michigan Tech was gathering the knowledge I need to be more involved with research and teaching in clinical practice."

SONGER AWARDS

Matthew '79 and Laura Songer '80 recently donated funds to the College of Sciences and Arts (CSA) that support undergraduate and graduate student research.

UNDERGRADUATE

Abby Sutherland,
"New Age-predicted Maximum Heart Rate Equation for Upper-body Exercise Prescription"
Department of Kinesiology and Integrative Physiology
Advisor: Steve Elmer

Gilliane Kenyon,
"Establishing the Impact of DNA Minor Groove Alkylation on DNA Replication and Transcription"
Department of Chemistry
Advisor: Marina Tanasova

GRADUATE

Rupsa Basu,
"Development of a Safe, Highly Immunogenic, Long-lasting, Bacteriophage VLP-based Chikungunya Virus Vaccine"
Department of Biological Sciences
Advisor: Ebenezer Tumban

Jeremy Bigalke,
"Orexin Control of Arginine Vasopressin in DOCA-salt Hypertension"
Department of Kinesiology and Integrative Physiology
Advisor: Jenny Shan

Shared Facilities

mtu.edu/research/shared

Advanced Power Systems Research Center
Jeff Naber, jnaber@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
Guy Meadows, gmeadows@mtu.edu

Microanalytical Facility
Andrew Burton, ajburton@mtu.edu

High Performance Computing Facility
Gowtham, g@mtu.edu

Research Centers and Institutes

mtu.edu/research/about/centers-institutes

Advanced Power Systems Research Center (APSRC)
Jeff Naber, jnaber@mtu.edu

Center for Agile and Interconnected Microgrids (AIM)
Rush Robinett, rdrobine@mtu.edu
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)
Guy Meadows, gmeadows@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)
Pasi Lautala, ptlautal@mtu.edu
Jake Hiller, jhiller@mtu.edu

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

Pre-College Innovative Outreach Institute (PIOI)
Cody Kangas, ckangas@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

"When I was struggling as an undergraduate, and trying to figure out my goals, I found mechatronics and robotics. Now whenever I do something related to automation, I always think of Iron Man doing experiments in his lab."

Prince Mehandiratta
Mechanical Engineering
Graduate Student

Inspired by comics, Prince Mehandiratta found his calling. He assists in an engineering lab that uses open-source software and industrial robots to help students from diverse backgrounds move into engineering careers. The technology makes day-to-day applications and assembly possible—food, medicine, cars, building materials.

Tomorrow needs automation.
Tomorrow needs Michigan Tech.

mtu.edu/magazine/mechatronics

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Today's cars are more advanced, fuel efficient, and complex than ever before—and will become more so. Interdisciplinary research is needed to rise with the oncoming wave of automation and big data. We work on the technology that keeps vehicles going in snowstorms, battlefields, space, and underwater. Together, we take mobility beyond the yellow lines.

Tomorrow needs mobility. Tomorrow needs Michigan Tech.

mtu.edu/tomorrow-needs