Research

MICHIGAN TECHNOLOGICAL UNIVERSITY / 2015

THIS ISSUE

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HEALTHIER, SAFER STENTS

AN OBSERVATORY IN THE SKY—
AND ONE UNDER THE ICE

THE HEALING STITCH

FENG ZHAO IS BUILDING A NEW KIND OF CELLULAR NANOSCAFFOLDING BY STITCHING TOGETHER FIBROBLAST CELLS—AN ARTFUL PROCESS SIMILAR TO CROCHETING

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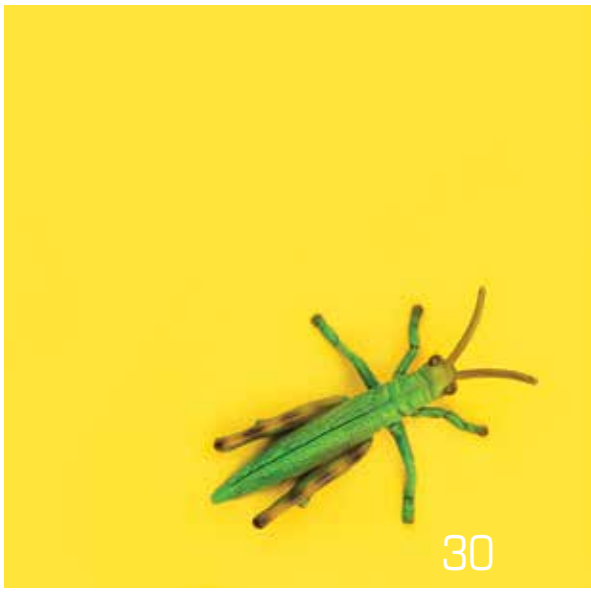

REGULAR FEATURES

Michigan Tech

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Research IN BRIEF

Michigan Tech Research Institute

FRIENDLY EYES IN THE SKY

The Michigan Tech Research Institute is using unmanned aerial vehicles, or drones, to map and monitor unpaved roads, track conditions inside culverts and on bridges, and monitor potholes. The goal is fewer people heading in to investigate compromised road conditions—which means safer workers and money saved.

Guiliang Tang

CREATING TOP CROPS

Using "small tandem target mimic" (STTM)—a technology of his own making—Associate Professor of Biological Sciences Guiliang Tang is studying genetic processes of maize, rice, and soy. His work, which is funded by a $2.5M NSF grant, could lead to the development of more productive, disease-resistant crops.

Jingfeng Jiang

EVOLVING ULTRASOUNDS

Healthcare professionals will be better prepared to read ultrasound elastography images after training with Biomedical Engineering Assistant Professor Jingfeng Jiang's new "virtual breast" software tool, funded by an NIH grant.

Tarun Dam

SWEET SCIENCE

Tarun Dam, assistant professor of chemistry, has unlocked a key to more and better pharmaceuticals: exploiting the functions of the structure of glycoconjugates, or sugar biomolecules.

FLAWS IN FOLDING

Ashutosh Tiwari shows us that small mistakes in folding whether it be paper or proteins can have big implications

Anyone can make a small mistake; it isn't until a bunch of these errors team up over time that a really big problem develops. This is true everywhere, from paper cranes to cells. Ashutosh Tiwari is researching how small errors in protein folding lead to cellular inefficiency and contribute to the onset of diseases we frequently associate with aging—and what can be done to correct them.

Unlike neat diagrams in textbooks, which show big gaps between cellular components like the nucleus and mitochondria, cells are a jumble. And yet, fighting disease requires combating a specific cause at a specific part of the cell—no easy feat.

"Imagine going sixty miles per hour on a country road," says Assistant Professor Ashutosh Tiwari. "No problem, right? It's easy to see everything, maintain speed, and get where you're going. Now try to drive at that high speed in the center of a busy city. There's so much traffic that it will be impossible to maintain the speed, and very little room for error while you're driving."

Tiwari is examining how errors in protein folding lead to cellular inefficiency and contribute to the onset of diseases associated with aging. He and his team are developing the tools to find and correct the mistakes by targeting the right error, or misfold.

Thanks to modern medicine, our population is living longer. However, this increased longevity has brought new challenges from diseases like Alzheimer's, Parkinson's, Huntington's, and ALS. This is due in part to declining proteostasis—the cycle of efficiently producing and recycling proteins within a cell—capability, leading to the disruption of protein function or misfolding due to oxidative stress, aging, or other factors.

"Increased oxidative damage of proteins associated with aging causes them to misfold and aggregate, and thus, disorders related to protein misfolding and aggregation are on the rise," says Tiwari.

Cells are, by necessity, highly efficient with materials. Some proteins, like signaling proteins, last just a few seconds, while others, like the fibrous proteins in muscle, can last a year or more depending on their purpose. But errors in the recycling process can lead to a buildup of misfolded proteins that are highly hydrophobic, meaning they have sites on them that are very sticky, collecting nearby materials that the cell cannot then recycle.

These sticky sites take away from cell function, and as these errors accumulate over time, a broad variety of diseases become increasingly likely to be triggered, despite the fact that they are not related in root cause.

Tiwari's lab has studied fluorescent dyes to better measure the hydrophobic nature in some of the proteins. They have tested new dyes made in collaboration with Professor Haiying Liu's research group that are tenfold more sensitive in measuring hydrophobicity than the commonly used dye ANS. Their work has led to better detection of protein misfolding errors with newly formulated dye compounds.

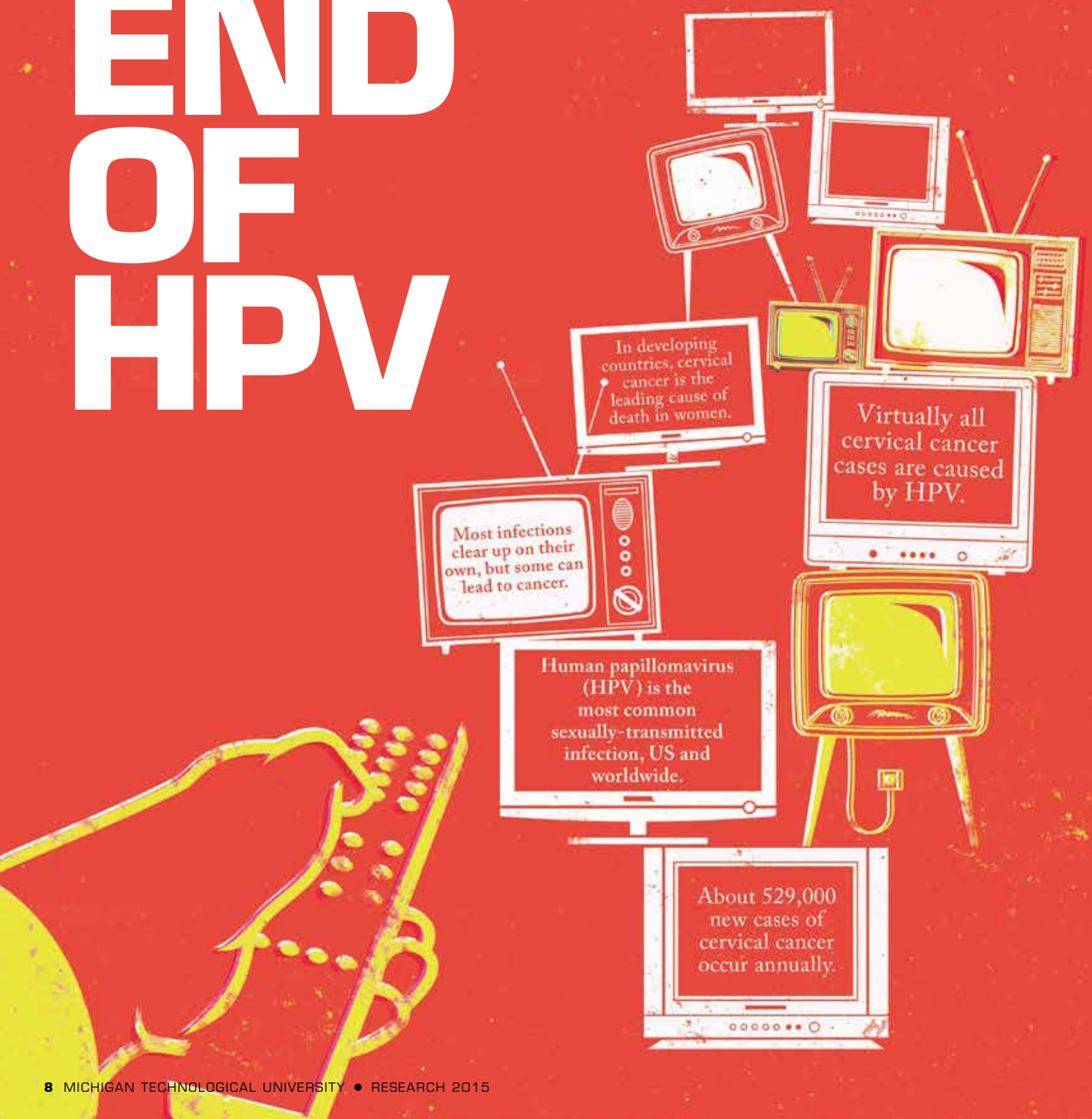
With molecular crowding playing a central role in how misfolded proteins behave, untangling this jumble is the first step to getting help where it is needed within the cell. Understanding the factors that regulate protein misfolding and their relationship to cellular toxicity will help us develop tools to combat these issues and formulate effective therapeutic strategies.

There are more than 6 million Americans currently living with Alzheimer s, Parkinson s, or ALS

nearly twice the population of Los Angeles.

THE END OF HPV

Ebenezer Tumban's next-generation vaccine research could be the HPV "power off" we've been searching for.



Human papillomavirus at high magnification

Undergoing a Pap smear—a simple test to detect cervical cancer—is a regular health habit for most American women. But in many other parts of the world (and some underserved populations in this country), women lack access to cervical cancer screening and treatment. As a result, some 275,000 women—80 percent of them in developing countries—die each year from the disease, which is caused by the sexually-transmitted human papillomavirus (HPV).

Molecular Virologist Ebenezer Tumban

The development of effective HPV vaccines in the past decade ushered in a new approach to preventing cervical cancer, as well as genital warts and other cancers caused by HPV, but current HPV vaccines have limitations. They don't work on all cancer-causing HPV types; they're expensive, at $390 for the three required doses; and they need refrigeration, complicating transport to developing countries.

That's why researchers like Michigan Tech Molecular Virologist Ebenezer Tumban are working on next-generation vaccines that would offer broader coverage and perhaps even treat, as well as prevent, HPV infection.

Like first-generation vaccines, Tumban's are composed of virus-like particles (VLPs), hollow shells that mimic viruses but can't infect because they contain no genetic material. Current vaccines have shells of L1 HPV proteins, which are not identical in all HPV types. To protect against many cancer-causing HPVs, those vaccines must contain individual L1 variants for each HPV type.

Tumban uses hollow shells from bacteria-infecting viruses, decorated with "lookalike" proteins from cancer-causing HPV types. These proteins trick the immune system into producing antibodies that defend against infection with real HPV types. The protein he uses, L2, contains sections that match many HPV types, so no need for individual variants.

"It's like using a single universal remote to control several TVs," Tumban said. "We're using a single protein to target many viruses that have the same amino acid sequence."

In experiments with mice, Tumban and collaborators at the University of New Mexico, where he received his post-doctoral training, showed that a vaccine containing a single L2 protein from HPV 16 protected against infection with about a dozen different HPV types.

Current vaccines protect against the two forms of HPV that cause 70 percent of cervical cancers, with little cross-protection against other HPV types. One vaccine also targets two forms that cause genital warts. Another vaccine is effective against nine HPV types. Tumban's vaccine could be a step forward, but he'd like to make that a giant stride by broadening the vaccine's protection to all 18 HPV types linked to cancer.

Tumban also is addressing other shortcomings of existing vaccines. He and collaborators at the University of New Mexico School of Medicine have converted the L2 vaccine to a formulation that can be stored at room temperature for up to a month. Now they're trying to extend that time. In addition, he and colleagues are working toward a lower-cost, single-dose HPV vaccine.

The final step: creating a vaccine that would combat existing HPV infections as well as prevent new ones. Tumban is seeking funding to use his vaccine-producing techniques to that end. ●

HPV AND CERVICAL CANCER

- Human papillomavirus (HPV) is the most common sexually-transmitted infection, US and worldwide. Most sexually active men and women get it at some point in their lives.
- Most infections clear up on their own, but some can lead to cancer.
- Virtually all cervical cancer cases are caused by HPV. HPV can also cause genital warts and genital, anal, and head and neck cancers.
- Worldwide, about 529,000 new cases of cervical cancer occur annually.
- In developing countries, cervical cancer is the leading cause of death in women.

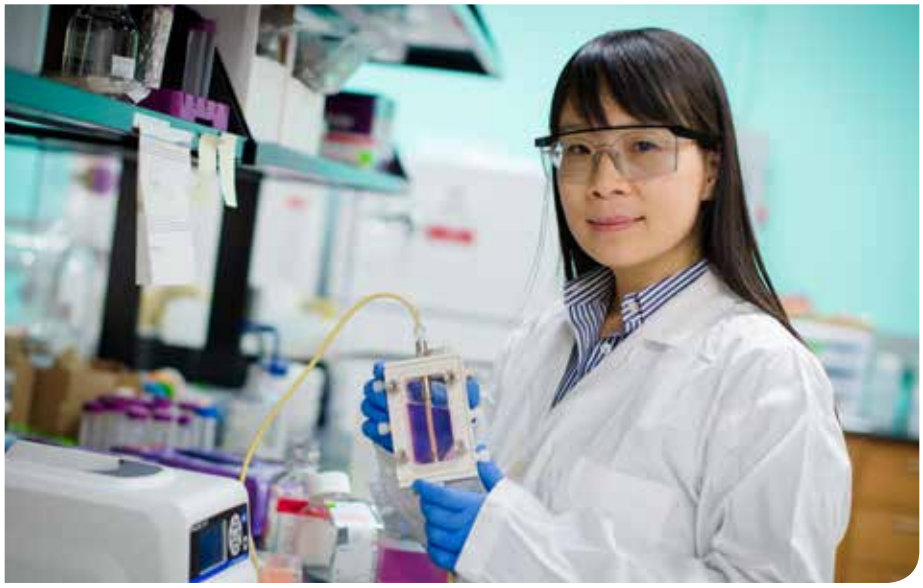
Sources: Centers for Disease Control and Prevention, World Health Organization, Wikipedia

500,000 papillomaviruses

equal the size of an average raindrop.

NANOSCAFFOLDING GOES NATURAL

Transcending synthetics, Feng Zhao's new nanoscaffolding created from fibroblast cells is set to revolutionize lab-grown tissues—and save lives.



In her biomedical engineering lab, Feng Zhao stitches fibroblast cells into scaffolding—a process that, down the road, may help folks heal better after heart surgery

Our cells aren't solitary. They exist in a vast, complex matrix that serves as the backbone for their duties. As cells proliferate, they use their surroundings to carry out our most basic biological functions, including growth and healing.

In all multicellular organisms—humans included—cells make their own extracellular matrix. When scientists try to grow tissues in the lab, they must provide a scaffold for cells to latch onto as they grow. These lab-grown tissues have proven to be of paramount importance, allowing us to repair and replace almost any part of our bodies.

Typically, researchers construct scaffolds from synthetic materials or natural or human substances. These methods have their pros and cons, but no scaffolds grown in a petri dish have been able to mimic the highly organized structure of the extracellular matrix made by living organisms—until now.

Feng Zhao, assistant professor of biomedical engineering, has developed a way to create a highly aligned scaffold out of fibroblast cells, the same cells that synthesize the extracellular matrix in living beings. Its fibers are 80 nanometers across—much smaller than previous lab-built scaffolds—and are made of the same mix of proteins and sugars found in the body.

"The blend of sugars and proteins mimics the body's biology, meaning it's completely biological," she says. "Since it's made of the same building blocks as natural scaffolding, we see a much higher biocompatibility when a lab-grown tissue is introduced into the body."

That agreeability could have enormous implications down the road; higher biocompatibility means fewer cases of organ and tissue rejection after operations. But Zhao's scaffolding not only imitates intricate biological formulas—it also gives cells the organized structure that they need to form specialized tissues.

Cardiac muscles, for example, need to grow in line with one another to be able to carry out their rhythmic contractions in efficient synchrony. Scaffolds of old were far too disorganized to provide a structured framework for their assembly. But when they're given Zhao's highly aligned scaffolding to grow upon, their ultimate structure closely mirrors what scientists would see in situ.

Zhao hopes her nanoscaffold will help make new types of lab-grown tissues and blood vessels possible in the near future.

"Coronary artery disease is the leading cause of death in the US, and small-diameter blood vessels are highly demanded by the market," she says. "We have been limited in the size of blood vessels we can generate in the lab, but now we have the scaffolding we need to make vessels that are six millimeters and smaller."

Those smaller vessels open many vital doors for biomedical engineers, Zhao explains. Implanted tissues often fail to thrive because they don't come with the same built-in network of capillaries that biological tissues have. Nanoscaffolding allows scientists to pre-vascularize tissues before implant, which will keep lab-grown materials alive.

Scientific merits aside, Zhao says her research's most important component is very human.

"My long-term goal is to save lives. But we're also meeting a critical market and medical need. This allows us to slow health problems—and keep people healthy."

mtu.edu/**nanofiber**

A bundle of 1 million nanofibers is similar to the width of a human hair.

THE HEALING STENT

It's natural, bioabsorbable, and capable of preventing harmful side effects: Jeremy Goldman explains why zinc may be the sweet solution to troublesome permanent stents.

Blocked artery, the doctor says. Too much plaque clogging the inside, curbing the flow of oxygen-rich blood to the heart and raising the risk of blood clots. Better widen the opening with a balloon-tipped catheter and insert a stent—a tiny wire mesh tube—to keep the artery propped open as it heals.

This familiar medical scenario is becoming even more common as our population ages and methods for detecting cardiovascular disease improve. Usually the procedure goes well, the artery wall heals around the stent within a few months, the artery stays open on its own, and that's that.

But sometimes, years after the stent has done its job, the once-helpful device reveals a downside. A permanent stent can trigger inflammation or clot formation, or it can break and injure the blood vessel. And even if nothing goes wrong, patients aren't crazy about having a piece of metal stuck in their vasculature forever. Wouldn't it be better if stents could just do their work and then, once they're no longer needed, disappear?

It would, and that's precisely the idea behind bioabsorbable stents, the goal of research in Jeremy Goldman's lab.

"In general, stents are not thought to be beneficial past one or two years," said Goldman, a biomedical engineer. "Making a bioabsorbable stent could be an attractive solution. You could have all the early beneficial characteristics, but none of the harmful later ones, and you'd be left with a natural artery."

The concept has been around for a while, and other research groups have been experimenting with various biodegradable materials for stents. Polymers looked promising because they perform well in other bioabsorbable medical devices, but polymer stents have proven weaker and harder to position than metal ones, so corrodible metals such as iron and magnesium also have been considered. So far, those metals haven't worked ideally in stents, either, leading some researchers to tinker with the metals' properties in hopes of improving their performance.

Goldman and colleagues took another approach. "We decided to jump out of the box. Instead of trying to manipulate the materials that were being used, we went with an entirely different metal: zinc."

CONTINUED ON NEXT PAGE

From top: Biomedical Engineer Jeremy Goldman, Graduate Student Patrick Bowen, and Materials Scientist Jaroslaw Drelich

Why zinc? Like iron and magnesium, it's found naturally in the body, where it contributes to essential biological functions, such as enzyme activity. There's even evidence that zinc helps keep arteries clear—an added benefit for a stent-making material.

In addition, "zinc's metallurgical aspects are well-established," said Goldman. "We know a lot about its mechanical behavior and elements that can be used with it to change its mechanical properties."

So Goldman and his collaborators—Materials Scientist Jaroslaw Drelich and Drelich's graduate student, Patrick Bowen—set out to explore zinc's behavior in the body. Once again, they took a novel path instead of treading in other researchers' footsteps.

"When we looked at the literature, we noticed that people were going straight from the bench to animal testing with stents, with nothing in between," said Goldman. Certainly the materials needed to be tested in animals, but did the researchers need to go to the expense of fabricating and testing zinc stents so early in the process? Not really.

Goldman's group realized they could test corrosion rates and breakdown products of zinc and zinc alloys by implanting simple wires made from those materials in rats' arteries. This way, metals could quickly and inexpensively be screened for further investigation. "If early results with the wire look good, then we can go ahead and make stents with the material and do large-animal testing," Goldman said.

Results of their first attempts, published in the journal *Advanced Materials* in 2013, showed that for the first three months after implantation, zinc degraded harmlessly in rat arteries, at a rate near that considered ideal for a bioabsorbable stent. After that, the rate gradually increased—an indication that a zinc stent wouldn't linger too long in the body.

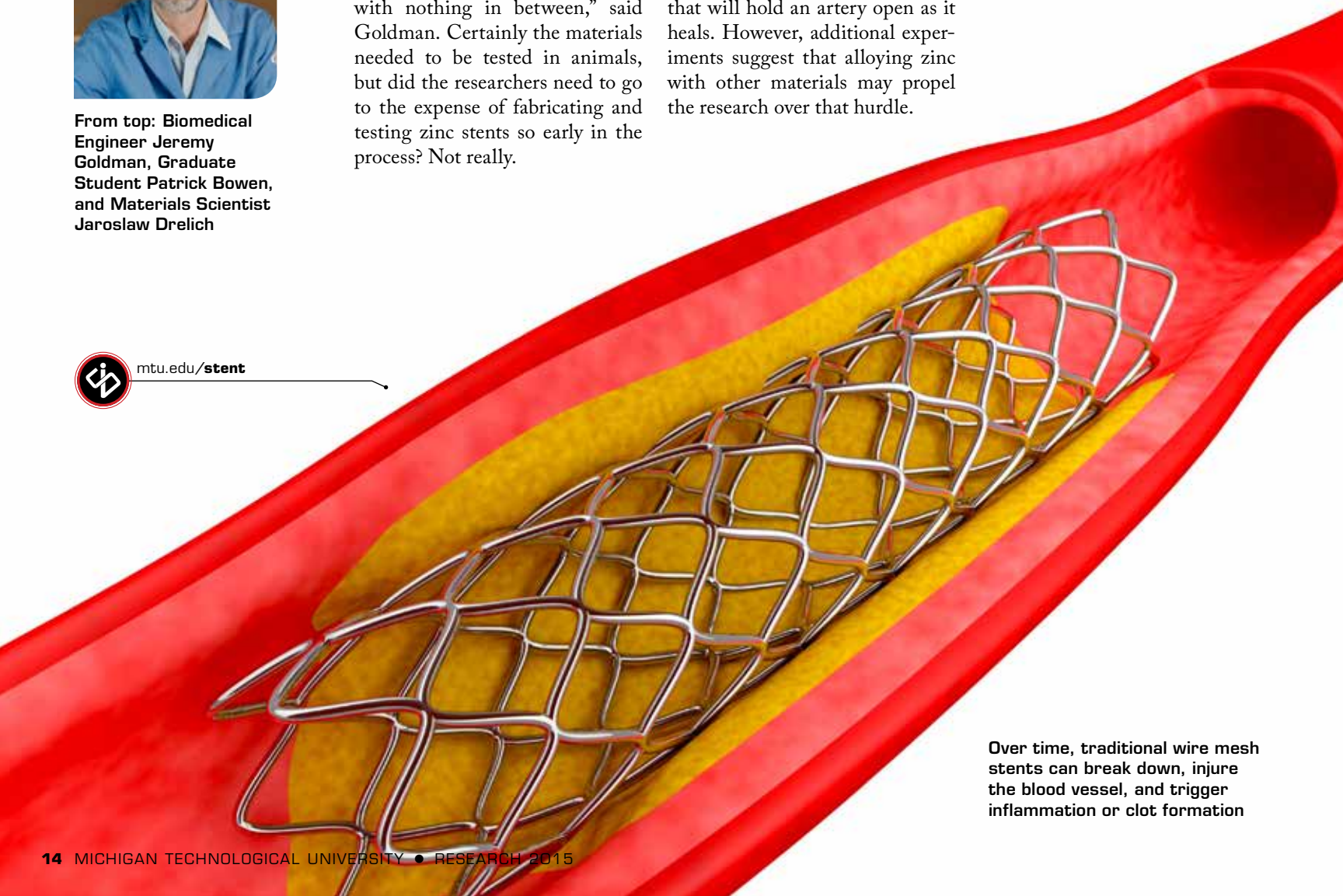
The only problem: pure zinc isn't strong enough to make a stent that will hold an artery open as it heals. However, additional experiments suggest that alloying zinc with other materials may propel the research over that hurdle.

Underway are biocompatibility studies of zinc's breakdown products, and progress toward animal testing of stents made from the most promising zinc alloys. A German company is making the stents, and collaborator Martin Bocks at the University of Michigan's Congenital Heart Center plans to implant them in pigs sometime in 2015.

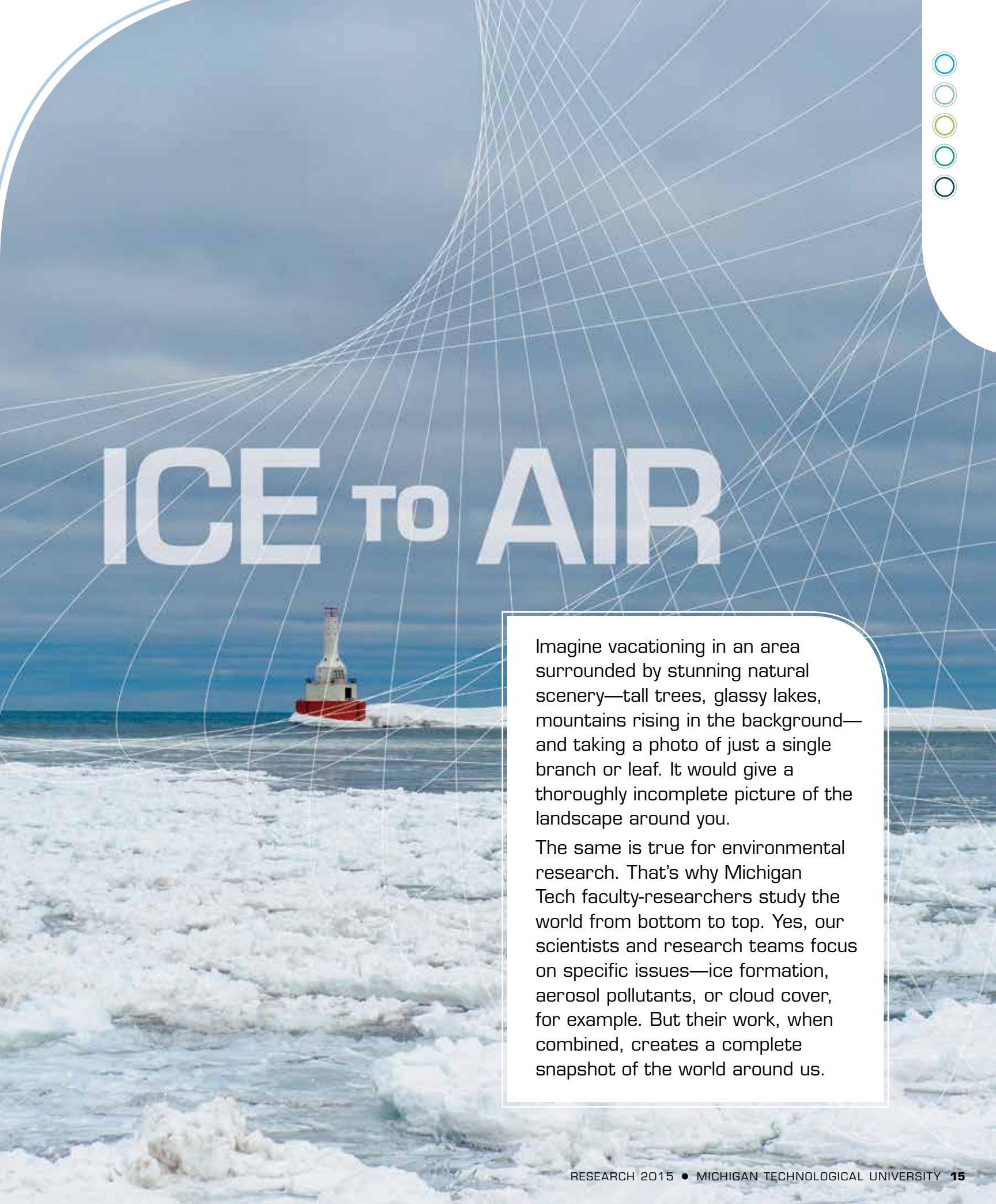
The project is an international, interdisciplinary effort that links industry and academia, clinicians and researcher scientists, said Goldman, who's also working with metallurgists in Israel on some of the zinc alloys.

"It's exciting to realize that it's possible to do all of this when you're based at Michigan Tech," he said. "I don't feel limited by geography."

mtu.edu/**stent**



Over time, traditional wire mesh stents can break down, injure the blood vessel, and trigger inflammation or clot formation



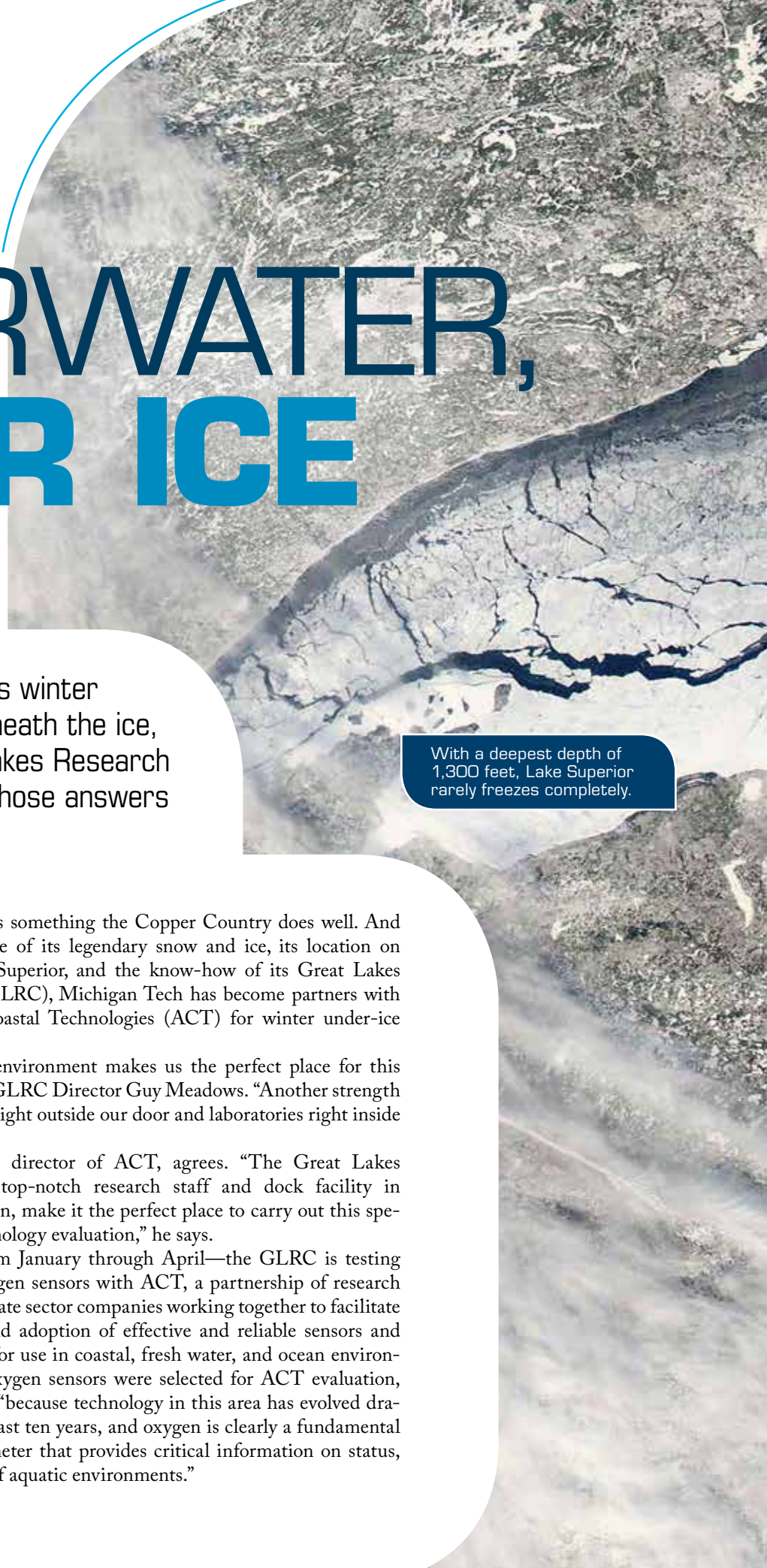
ICE TO AIR

Imagine vacationing in an area surrounded by stunning natural scenery—tall trees, glassy lakes, mountains rising in the background—and taking a photo of just a single branch or leaf. It would give a thoroughly incomplete picture of the landscape around you.

The same is true for environmental research. That's why Michigan Tech faculty-researchers study the world from bottom to top. Yes, our scientists and research teams focus on specific issues—ice formation, aerosol pollutants, or cloud cover, for example. But their work, when combined, creates a complete snapshot of the world around us.

UNDERWATER, UNDER ICE

Want to know Lake Superior's winter secrets? The answers lie beneath the ice, and Michigan Tech's Great Lakes Research Center is hot on the trail of those answers on several fronts.



With a deepest depth of 1,300 feet, Lake Superior rarely freezes completely.

Winter is something the Copper Country does well. And because of its legendary snow and ice, its location on Lake Superior, and the know-how of its Great Lakes Research Center (GLRC), Michigan Tech has become partners with the Alliance for Coastal Technologies (ACT) for winter under-ice instrument testing.

"Our arctic-like environment makes us the perfect place for this kind of work," says GLRC Director Guy Meadows. "Another strength is having the water right outside our door and laboratories right inside the door."

Mario Tamburri, director of ACT, agrees. "The Great Lakes Research Center's top-notch research staff and dock facility in Houghton, Michigan, make it the perfect place to carry out this specific under-ice technology evaluation," he says.

This winter—from January through April—the GLRC is testing seven dissolved oxygen sensors with ACT, a partnership of research institutions and private sector companies working together to facilitate the development and adoption of effective and reliable sensors and other technologies for use in coastal, fresh water, and ocean environments. Dissolved oxygen sensors were selected for ACT evaluation, Tamburri explains, "because technology in this area has evolved dramatically over the past ten years, and oxygen is clearly a fundamental water quality parameter that provides critical information on status, trends, and health of aquatic environments."

Probing Icy Depths
Inaccessible to human hands, instruments under the ice can measure pH, oxygen levels, temperature, water currents, and more.

Ice cover can vary between 40 and 95 percent most years.

Building and Breaking Ice
Modeling fits observational data like a glove for wintertime ice studies the computer generated data helps site selection while field work refines models.

The lake last completely froze over in 1997.

Canal Cameras
Underwater cameras in the Keweenaw Waterway capture images of mudpuppies, settling silt, and other winter water mysteries.

PHOTO: COURTESY OF NOAA

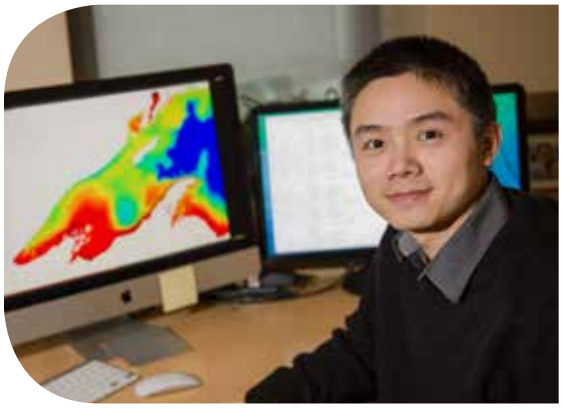
An arctic lab, right outside the back door: GLRC Director Guy Meadows (right) says the Keweenaw is "the perfect place for this kind of work"

A "SUPERIOR" COMPUTER

Pengfei Xue, assistant professor of civil and environmental engineering, is leading the work of modeling ice formation and distribution, using a high-tech GLRC supercomputer named Superior.

Instead of braving the ice, snow, and frigid temperatures, Xue is developing computer programs that simulate the physics of the lake. His models will be able to track the time and strength of ice formation, the variability of ice distribution, changing temperatures, currents, and the way dissolved and suspended matter moves with the flow.

By integrating computer model results and observational data, Xue believes that scientists will be better able to choose appropriate sites for collection of actual samples. "The observational data helps us make an accurate model, and the model helps us know more than we can observe," says Xue.



When this alluring ACT research opportunity arose, the GLRC was ready. Last winter, GLRC scientists and engineers built and deployed a cabled observatory under the ice off the Center's dock on the Keweenaw Waterway, which connects two sections of Lake Superior. The observatory's collection of instruments includes an Acoustic Doppler Current Profiler—a multi-probe that measures nine water quality parameters such as temperature, amount of dissolved oxygen, pH, and water turbidity or cloudiness. The observatory is mounted on the bottom of the waterway, seventeen feet below the surface, and data collected is transmitted back to GLRC researchers via an armored underwater cable.

For its first year of ACT research, the GLRC plunged a rack containing seven underwater dissolved oxygen sensors into the water off its dock. After ice formed, holes were kept open so that researchers could bring up two water samples a day from the exact depth of the sensors. Sarah Green, professor of chemistry and a GLRC faculty member, is conducting a chemical analysis of the samples to determine the standards by which each sensor will be compared.

After the winter tests are finished, the sensors will be moved to another ACT test site for testing under different weather and water conditions. Next winter, the GLRC plans to test and deploy other new instruments.

As exciting as it is to partner with ACT, Meadows has his eye on an even bigger prize. He is working with Tech's Sustainable Futures Institute on a bi-national grant with Canada to build cabled observatories in all five Great Lakes. Michigan Tech is seeking funding from the National Science Foundation (NSF), while the Canadians are applying for $18 million through the Canadian Foundation for Innovation. The NSF's decision is expected in 2016.

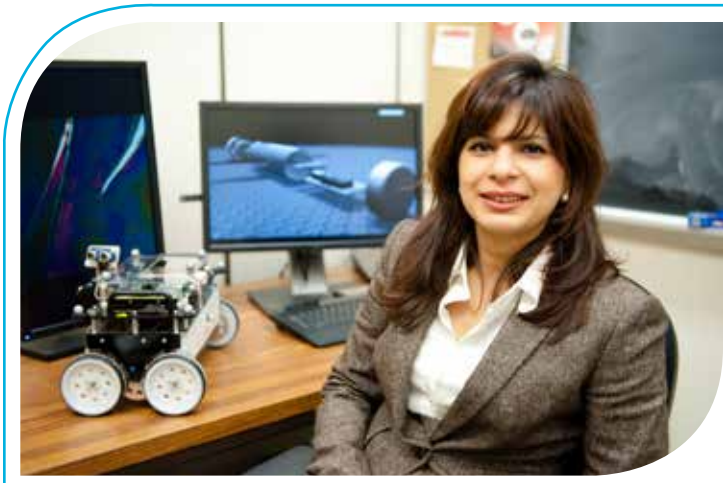
"We want to be *the* center for Arctic-type water research," Meadows explains.

Meanwhile, the GLRC has its fingers in other winter-water pies. Last winter, researchers used data from another under-ice observatory at the nearby South Entry to the Keweenaw Waterway to measure currents, ice thickness, ice movement, and the impact of ice on the historic South Entry Lighthouse. The work was done in collaboration with University of Michigan researcher Tony England and funded by the US Department of Energy as part of a feasibility study for offshore wind power installations. "They needed to know what the ice loading would be on a wind tower," says Meadows.

This winter, the cabled observatory will be transmitting data to the Internet using a high-def video camera with underwater lighting for nighttime viewing. Researchers—and anyone else—can also listen to the lake, thanks to sensitive underwater hydrophones installed by Andrew Barnard, assistant professor of mechanical engineering-engineering mechanics.

When they're not focused under the water, researchers will be gathering data from the winter meteorological station on the roof of the GLRC, measuring solar radiation, wind speed, and direction. That work can also be watched in real-time; webcams facing the Keweenaw Waterway will transmit information on ice formation and breakup. ●

mtu.edu/**winterwater**



COLD-WEATHER WOES? ROBOTS TO THE RESCUE!

Winter in the Keweenaw means snow, more snow, and ice. What happens, then, if the power goes out?

In the not-so-distant future, it could mean hours instead of days of cold and dark, thanks to Nina Mahmoudian's robotic system.

Mahmoudian, an assistant professor of mechanical engineering-engineering mechanics at Michigan Tech, is working with Wayne Weaver, the Dave House Associate Professor of Electrical Engineering, and a team to develop robots that can restore electricity temporarily while human technicians work on a permanent fix. The efforts are supported by the Center for Agile Interconnected Microgrids (AIM).

The plan: robots scurry safely to a site and determine the problem, then hook up a microgrid to provide power until the real grid can be restored. They can't provide power forever, but four robots can form a microgrid; ten microgrids could provide temporary power to a small neighborhood; and 100 microgrids could relight a community.

"This is the solution," says Mahmoudian. "The robots can be human hands. They can go where human hands can't—or would rather not."

Mahmoudian hopes that within three years, her robots will be ready to take on real-world power outages, and not just those caused by snow or ice. "We want them to be deployable in all kinds of different emergencies," she says. "This approach will free up manpower to put more effort into saving lives while the robots establish power and communications."

MAKING **GREENER** LEANER

Kathleen Halvorsen weighs the woody biomass pros and cons, researching methods for reducing negative social and natural effects of harvesting bioenergy crops.

There's no denying we're at an energy crossroads. As the effects of present-day consumption mount, researchers continue to explore alternative energy sources. Thankfully, there are many promising options—but with each possibility comes a list of pros and cons.

Exploring how to weigh the positives and negatives of one promising option, woody bioenergy, is the work of Kathleen Halvorsen, a professor in both the Department of Social Sciences and the School of Forest Resources and Environmental Science. With the help of many interwoven grants (most recently a $4.8M National Science Foundation award), she and her team are researching bioenergy issues throughout the Americas. Her research spans six nations—Argentina, Brazil, Canada, Mexico, Uruguay, and the US—and investigates the socioeconomic impacts of woody bioenergy.

"Woody bioenergy is used for a variety of things," Halvorsen says. "It provides heat, power, liquid transportation fuel. The team is looking at the use of soft and hardwood tree species and palm and jatropha oil."

All of these bioenergy crops present challenges, and Halvorsen's team aims to bridge the social, natural, and engineering science matters unique to each medium and region.

Kathleen Halvorsen and a 95-person international team (some of whom are pictured at left) research the impacts of bioenergy on communities around the world

"It's important to ask how these new energy sources impact human and ecological communities. How can we develop ways to maximize the good and minimize the bad when we're harvesting woody biomass?"

Halvorsen and her 95-person international team are exploring different issues in each of the project's six nations. In Argentina, for example, eucalyptus farms need to find an optimized way to grow their crops without disrupting bird populations or pollinators, like bees and other insects. The farmers, whose livelihoods depend on a good harvest, are equally important in the project's scope.

"Are there ways to help human communities get great benefits from the production of different bioenergy crops while minimizing negative social and natural impacts?," she asks.

Her project's success balances on international, interdisciplinary collaboration. With researchers' varied backgrounds (including forestry; social science; civil and environmental, geological, and chemical engineering experts at Michigan Tech alone), Halvorsen says the diverse expertise of her colleagues provides one of the most comprehensive analyses of bioenergy crops to date.

"At the end of the project," she says, "we will be able to advise communities about whether or not they want to attract bioenergy companies . . . about the environmental impacts of bioenergy production . . . about energy policy at state, national, and international levels."

Halvorsen also sees her work as a stepping-stone in a larger undertaking: the eventual de-carbonization of our global energy system.

"Ultimately, my research priorities are threefold," she explains. "We're studying ourselves—how to develop good teamwork skills and how scientists can be better interdisciplinary, international scholars. We're studying energy tradeoffs—how we can shift the energy balance in our favor. And we're studying biodiversity—how we can protect dimensions of the world that are threatened."

She says one of the most crucial components of her research will be her team's policy recommendations.

"Woody bioenergy is an important climate-change mitigation tool, and it is incredibly important that we increase our understanding of how to best use it on an international scale."

mtu.edu/**bioenergy**

HOW WARM IS TOO WARM?

Researcher Molly Cavaleri turns up the heat in Puerto Rico's El Yunque National Forest to determine how the climate warming trend is affecting tropical rainforests.

Molly Cavaleri is spending a lot of time in Puerto Rico's El Yunque National Forest this winter, but she's no snowbird. She's leading a team of scientists who are conducting the first-ever field study of the impacts of climate change on tropical rainforests. The US Forest Service and the US Department of Energy are funding the research project, called Tropical Response to Altered Climate Experiment (TRACE).

Cavaleri and her colleagues and graduate students have barely begun, and already Michigan Tech master's student Alida Mau has presented disturbing findings. Speaking at the International Union of Forest Research Organizations meeting in Salt Lake City last October, she reported that leaf temperatures in the canopy—the topmost branches of the trees—often exceed the optimum temperatures for photosynthesis. "That means things could get worse for tropical forest carbon dioxide uptake as climate warming increases," Cavaleri points out.

A tree physiologist and assistant professor in Michigan Tech's School of Forest Resources and Environmental Science, Cavaleri is thrilled to be leading the study, especially since her co-researchers are two women: Tana Wood from the Puerto Rico Conservation Foundation, who is an adjunct scientist with the US Forest Service International Institute of Tropical Forestry; and Sasha Reed with the US Geological Survey (USGS).

"It's unusual for three early-career women to be spearheading a project of this size and significance," Cavaleri observes.

Why is TRACE so significant? Forests of all kinds help control greenhouse gases like carbon dioxide because trees take in and store more CO_2 than they put out. But unlike forests in temperate climates, where temperatures vary widely from season to season and trees have adapted to those changes, tropical forests grow in consistently warm climates, and no one knows how or even if they

Sasha Reed, Tana Wood, and Molly Cavaleri are spearheading a climate study in a Puerto Rican tropical rainforest

Well above the forest floor, temperatures are making it difficult for even tropical foliage—which draws in CO_2—to survive

can acclimate if those climates get hotter. And they are getting hotter, climate scientists confirm. "Within twenty years, the new minimum temperatures in the tropical rainforests will be hotter than the current maximums," Cavaleri says.

Their study involves manipulating the environment by warming the soil and small plants on the forest floor, as well as the leaves and branches of the canopy. The researchers will be using infrared lamps to warm the soil, roots, and forest floor plants, and warming cables to warm branches and leaves above. Then they'll take measurements, collecting data about the responses of the various components of the forest.

"We want to know how sensitive tropical forests are to warming, what physiological changes it will cause, and particularly how it affects the trees' ability to store CO_2," Cavaleri explains. "If we tip them over a threshold where it's too warm, they may not be able to take up as much CO_2. They may even start giving off more CO_2, which could lead to more warming."

Cavaleri, Wood, and Reed hope to use the data they collect to help develop better predictive models of the effects of climate change on tropical forests, an effort funded by the USGS Powell Center. "The data will help us understand what is happening globally and what is likely to happen in the future," Cavaleri says.

mtu.edu/**rainforest**

Atmospheric science researchers at Michigan Tech no longer have to cross their fingers for cooperative weather—the University's innovative new cloud chamber allows them to head into the lab and make their own.

CLOUD CONTROL

Michigan Tech s new 15 ton research chamber brings clouds down to earth, allowing scientists to study the atmosphere at ground level

If Raymond Shaw had his way, we might rethink what we call our home planet.

"If you imagine looking at Earth from outer space, what you see is really only a little bit of earth," says the Michigan Tech atmospheric physicist. "You actually see a lot more clouds and oceans. We call it Planet Earth, but it's really Planet Cloud."

Clouds are key to so many natural processes—climate in particular—that it's hard to overstate their importance. They play a dual role: low, fluffy clouds tend to cool us by reflecting sunlight, while clouds in the upper atmosphere act as a blanket, helping Earth retain heat. However, studying clouds is hard, especially those at high altitudes or over the Arctic, where Shaw and his colleagues have focused some of their recent research.

"You're in an aircraft going a hundred meters a second, and it's impossible to replicate what you've just seen," says fellow physicist Will Cantrell. "You know the old Taoist saying, you never step in the river twice? You never fly through the same cloud twice either."

But now, on the ground floor of Michigan Tech's Dow Environmental Sciences and Engineering Building, scientists have solved the problem by bringing clouds down to earth.

"In our new chamber, you can make virtually the same cloud as many times as you need, until you really understand it," Shaw says.

The fifteen-ton cloud chamber, funded by a $1.4 million grant from the National Science Foundation, arrived in March 2014. It's not the world's first cloud chamber, but it is unique.

By carefully controlling temperature and pressure, it can create turbulence. That means researchers can mimic conditions ranging from an inversion layer (like the ones that trap smog in Los Angeles) to the powerful forces that build thunderheads.

It can also recreate conditions ranging from stratospheric to sea-level, from equatorial to arctic. "In principle, we could study ozone chemistry problems," says Shaw.

The chamber was designed and built by Russells Technical Products of Holland, Michigan, which specializes in environmental test chambers. Michigan Tech alumnus Jim Bench led the project.

"It's a unique piece of equipment, the only one like it," says Bench, who earned a bachelor's in mechanical engineering in 2003. "It was a really cool project, and it made me proud to serve Michigan Tech, since Tech served me so well with my education."

All the cloud-making action happens inside a big, blue steel box, two meters square and one meter high. It is lined with electropolished steel dotted with a grid of holes; they introduce moisture into the chamber from trays underneath.

The pressure and temperature are regulated via a delicate interplay of compressors, pumps, heaters, and a refrigeration system.

The instrumentation can be controlled remotely, which is convenient not only for the Michigan Tech scientists; it's also a plus for researchers from other universities and labs, who will be able to conduct experiments from anywhere in the world. And a one-meter-wide cylinder (dubbed the Pi Can for its 3.14-meter circumference) can be inserted into the chamber, opening the door to research that can only be done in the round.

The scientists are calibrating the cloud chamber and planning for the science to come. "Right now, we're concentrating on arctic stratus clouds, which have water and ice present in them at the same time," Cantrell says. "You have these long-lasting systems that shouldn't even exist. Now we can make them right here."

Other projects are also in the works, including one led by Michigan Tech Physicist Claudio Mazzoleni and his wife, Chemist Lynn Mazzoleni. They aim to better understand why aerosol particles mysteriously collapse in on themselves as they drift from North America across the Atlantic to the Pico Mountain Observatory in the Azores.

The cloud chamber has some very down-to-earth applications as well, Shaw notes. "We also hope to address some very immediate, practical questions, like 'Is it going to rain on my picnic Friday?'"

mtu.edu/**cloudchamber**

UP IN THE A

Atop a volcanic peak deep in the eastern Atlantic, Tech researchers sample and study aerosol particles—and determine how they may affect Earth's climate.

Deep in the eastern Atlantic, roughly 900 miles west of Portugal, lies the tiny island of Pico. On maps, it looks like nothing—hardly more than a pinpoint in a sea of blue. But to atmospheric researchers, the remote island's towering Pico Mountain holds the key to understanding how aerosols may impact climate change.

Pico Mountain is one of nine volcanic islands that make up the Azores archipelago. Its size, however, sets it apart: at nearly 8,000 feet, it's one of the highest mountains in the Atlantic and more than twice the elevation of neighboring peaks. To hike to the top is to enter an entirely new world, up in the clouds.

It is the high altitude—along with Pico Mountain's isolated Atlantic location—that make it the ideal place to study aerosols. These high-in-the-sky aerosol particles are what interest Michigan Tech researchers. For years, they have worked with collaborators to sample particles atop the peak at the Pico Mountain Observatory, learning more about the sources and characteristics of aerosols. These aerosols have a large but not completely understood influence on our atmosphere.

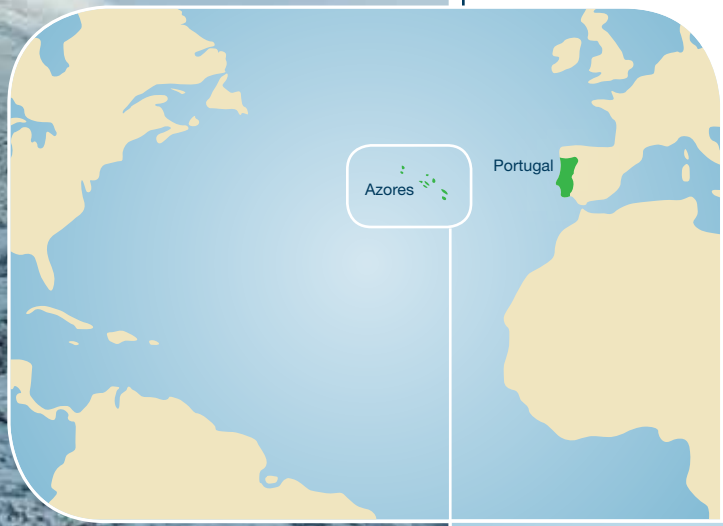
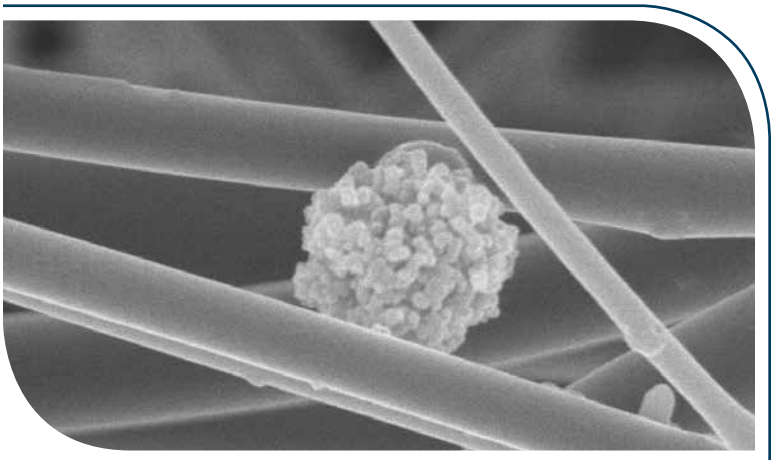


PHOTO: JACQUES HUEBER, INSTAAR, UNIV. OF COLORADO

An atmospheric research observatory sits atop Pico Mountain, the tallest of nine volcanic islands that make up the Azores archipelago in the eastern Atlantic



THE AEROSOLS–CLIMATE CHANGE CONNECTION

Studying the age, shape, color, and water content of aerosol particles is critical to understanding the role they may play in climate change.

Color

One of the big variables in climate change surrounds the amount of the sun's energy that reaches the surface of the Earth, and aerosols play a significant role. For example, if a particle is light-colored, it will reflect the sun's light back into space. However, dark-colored particles will absorb light, making it possible to capture more of the sun's energy.

Water Content

The water content of aerosols makes a massive difference to the nature of cloud cover and how much of the solar energy makes it through the atmosphere. While researchers are on the case, these are questions that are yet to be answered.

Age and Shape

Soot particles age in the atmosphere and this aging affects their ability to form droplets and be hydrophilic—attracting water to form clouds or precipitation. This also makes a difference as to whether they reflect and scatter incoming sunlight or they absorb it.

At Pico, researchers have observed soot particles taking forms not seen at observatories on land. In particular, their compact shape seems to be the result of long-range transport and continual processing through clouds, something that takes on substantial importance considering oceanic atmospheric conditions over a majority of the planet.

These shapes and forms are important because, while we understand quite well how greenhouse gases work and their quantities in the atmosphere, aerosols also play a big role on climate—and their chemistry, optical properties, and evolution are not well understood.

The Pico Mountain Observatory was founded thirteen years ago by a collaboration headed by Michigan Tech's Richard Honrath, a former professor in the Department of Geological and Mining Engineering and Sciences. His specialty was atmospheric sciences, and he used the observatory for the study of trace gases.

Honrath passed away in 2009, but Tech researchers maintained the lead research role at Pico, shifting focus from trace gases to aerosols.

"The future of the observatory was in question," says Lynn Mazzoleni, associate professor of chemistry and one of the current collaborators at Pico Mountain. "But it was the perfect location to study aerosols, which have potentially huge consequences for climate change."

The new collaboration features Tech faculty Lynn Mazzoleni (chemistry), Claudio Mazzoleni (physics), Noel Urban (CEE), Judith Perlinger (CEE), and Chris Owen (MTRI). Also involved are collaborators from the University of Colorado and the University of Illinois, as well as Universidade dos Açores and the Instituto de Meteorologia in Portugal.

Their goal is to trace the path and origin, as well as study the shape, color, and water content of particles. Pico is an ideal spot to conduct such research.

Air near the ocean's surface contains churned-up particles: decaying marine life and local emissions. But rise above the boundary layer—the point where the dense air near the ocean's surface gives way to the thinner air at altitude—and you'll experience a visible separation from the opaque layer below.

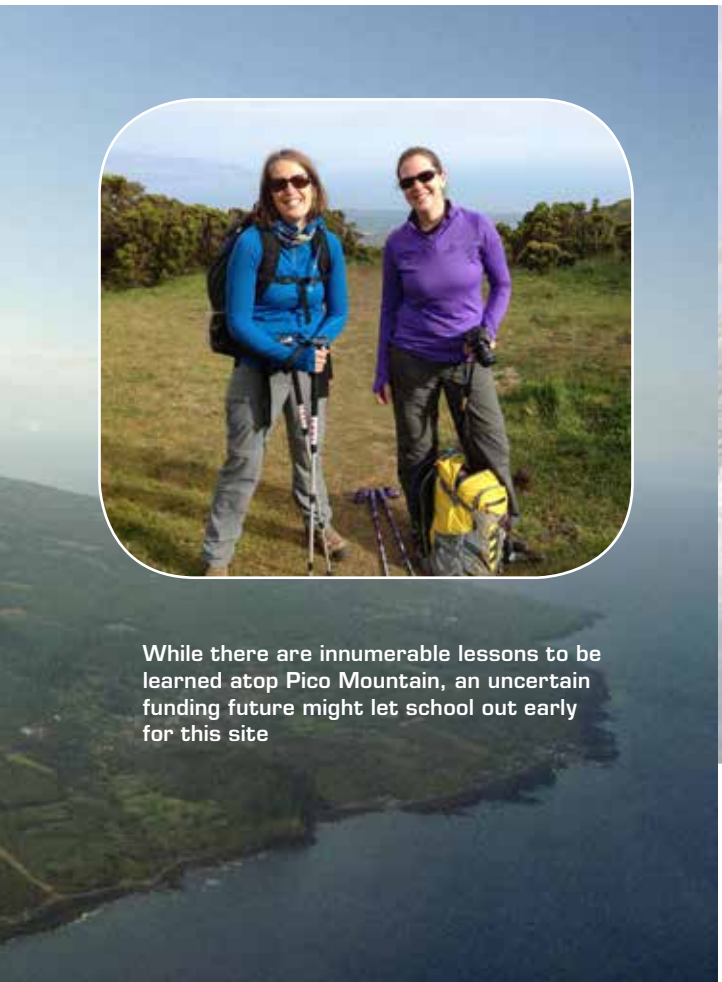
The air at this height is clearer, and aerosol particles that inhabit it often come from much further away—sometimes thousands of miles. The site is influenced by both the jet stream and trade winds, thus particles can come from either southeast or west depending on weather patterns.

Pico Mountain's high altitude means researchers can study older aerosols and—thanks to computer models—back trace them to their source. Researchers have found particles rich in iron oxides from the Sahara, and they frequently see soot particles from wildfires that can be traced back more than a week to western North America.

Lynn and Claudio Mazzoleni

In addition to the research, Mazzoleni strives to cultivate awareness through public education. This past year, grant funds sponsored Lorentyna Harkness, a certified science teacher and Michigan Tech graduate student, in her development of online videos and other outreach materials to illustrate the importance of climate study and the opportunities for learning provided by Pico Mountain.

It's what Mazzoleni gets back to when talking about the future of the site. "Our funding, or most of it, is up, and we're applying for new grants," she explains. "There's so much more we need to learn here."



While there are innumerable lessons to be learned atop Pico Mountain, an uncertain funding future might let school out early for this site

PICTURE IT PRINTED

A snapshot of Associate Professor Joshua Pearce's 3D-printed world

Ditch the online ordering and stacks of catalogs. If you can imagine it, Associate Professor of Electrical and Computer Engineering Joshua Pearce can probably 3D print it for pennies on the dollar—and so can you. Pearce and his team of students are working to revolutionize open-source 3D printing, finding solutions and creating products of all scopes and sizes.

1

1 PLASTIC FOR PENNIES

Why buy plastic filament when you can make your own nearly for free? According to Pearce, average old plastic milk jugs—cleaned, shredded, and run through a RecycleBot—can become quality 3D printer filament. And since processing milk jugs uses significantly less energy than traditional recycling, you'll be doing the world an environmental favor as well. Win-win.

2 SYNTHESIZING WITH SUNSHINE

3D printing has many attributes, but portability hasn't been one of them—until now. Pearce's latest development is a set of open-source solar-powered 3D printers—one designed for schools and businesses, the other for remote communities. The first features an array of solar photovoltaic panels and a stand-alone printer, which can be used to print anything from toys to science lab equipment. The second system is a smaller, more-portable RepRap. "If you're in the Peace Corps going to an off-grid community, you can take this printer in your suitcase," Pearce says. "It's a mobile manufacturing facility that can make whatever you and the community need or value. It has nearly unlimited flexibility."

2

4

3

4 MORE THAN DECOR

First Celtic crosses, then the world. Pearce's Fall 2014 Open-Source 3D Printing class—a mix of fifty undergraduate and graduate students—was the largest group of students ever to come together and build their own 3D printers. After completing the printers, students were tasked with several projects of increasing complexity: a piece for a climbing "rock" wall, Celtic knot décor, appropriate technologies for sustainable development, and improvements to the printers themselves. For one assignment, students teamed up and used their 3D printers to provide high-level solutions to Michigan Tech researchers in need. All told, the class produced millions of dollars of value by freely sharing their open source designs.

5 BACTERIAL SLIME: IT'S WHAT'S FOR SUPPER

When Pearce isn't busy working to open-source the world, he's thinking about feeding it. A new research project led Pearce to write and publish his latest book, *Feeding Everyone No Matter What*. In it, he explores what may sustain the human race in the event of catastrophic crop failure. (Spoiler alert: it's not burgers and fries.) Regardless of the scenario, Pearce found that wood, leaves, and fossil fuels converted to food using combinations of bacteria, bugs, fungi, and rats would be the most viable options. ●

mtu.edu/**3dprint**

mtu.edu/**feedtheworld**

3 A SMARTER SYRINGE

Do a quick online shopping search and you'll find that syringe pumps—equipment commonly used in medical and research labs to dispense precise amounts of liquid—will set you back hundreds or thousands of dollars. Pearce's new open-source syringe pump design library could make those hefty price tags a thing of the past. As Pearce and his students proved, pumps can be produced quickly on a RepRap 3D printer, are functionally equivalent to commercial systems, can be operated with a smartphone, and are completely customizable.

5

CAREER AWARDS HONOR TECH RESEARCHERS

As one of the most prestigious awards researchers can earn, the Faculty Early Career Development (CAREER) program recognizes junior faculty across the nation who demonstrate the role of teacher-scholars through groundbreaking research, excellent education, and the integration of their research with their teaching. Awardees are chosen for their promise to become the next generation's academic leaders. This year, five Michigan Tech faculty—the highest number in school history—were honored with the award, which is administered by the National Science Foundation. Through these awards, researchers' projects are funded for five years—to the tune of up to $500,000.

NEW TOOLS PUT NANOSCALE COMPUTER CHIPS IN THE FAST LANE

Zhuo Feng, electrical and computer engineering, says traditional computer aided design (CAD) tools are used to build every chip in the world, but the software used to design the chips hasn't kept pace with the hardware being created. The complexity of these nanoscale integrated circuits makes it increasingly difficult to design, optimize, and verify their designs with existing tools. Now, Feng aims to develop new CAD algorithms that will help chip designers take advantage of emerging manycore heterogeneous processors—integrating both traditional CPUs and graphics processing units—saving time and money along the way. "We're making an impact on algorithm innovation and also solving new, challenging problems that are becoming more and more important in nanoscale chip design," Feng says.

CARBON NANOTUBES POISED TO SPEED UP INTEGRATED CIRCUITS

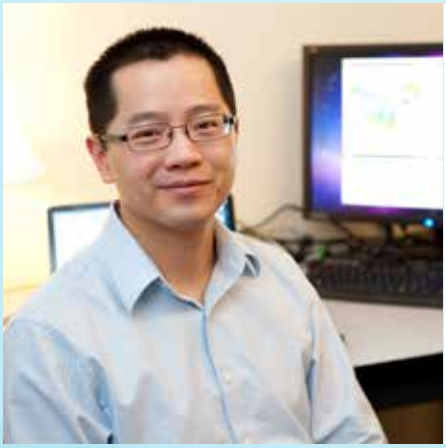
Shiyan Hu, electrical and computer engineering, is set to design new chips that will greatly increase speed by reducing interconnect delay. Copper wires in a typical computer chip are already so narrow that in order to do more things, you need billions of transistors on a single chip. That puts the brakes on speedy computerized devices. "There's a fundamental physical limit of the copper wires that we use today," Hu says, "and we're there." To overcome that limit, Hu is designing chips that replace copper wires with carbon nanotubes or graphene, which have superconductive powers and are better suited for circuitry. "Twenty years from now, everything will be made of new materials. This is a first step."

ARTIFICIAL LOWER LEG RESTORES AMPUTEES' MOBILITY AND AGILITY

Mo Rastgaar, mechanical engineering-engineering mechanics, will be further developing his powered ankle-foot prosthesis. The prosthetic joint is multi-axis, meaning it can move the foot from side to side as well as up and down—a new approach to the design. The prosthesis is robotic, with sensors on the foot to detect how an amputee is walking, which will make movements look and feel more natural. One key to the design's success is the location of the motor. "The current designs put the motor close to the ankle," he says. "If we put the mass from the motor close to the knee or hip, the amount of energy required by the body to move it is far less."

UNLOCKING THE MYSTERY OF IRON-SAFEGUARDING PROTEIN

Tolou Shokuhfar, mechanical engineering-engineering mechanics, has developed a pioneering way of looking at ferritin protein. The biomolecule stores iron in the body in a non-toxic, mineralized form and releases it safely. When ferritin proteins malfunction, degenerative diseases—such as Alzheimer's and Parkinson's—begin appearing. With her CAREER award, Shokuhfar plans to compare healthy and unhealthy ferritin by encapsulating the protein in a microscopic graphene bubble and observing the fully hydrated molecule with an electron microscope. "It will allow us to probe the connection between disease and ferritin, and will truly bring up a new research field," Shokuhfar says.



TURNING BIG DATA INTO THE BIG PICTURE

Chaoli Wang, computer science, is setting out to find an effective way to visualize dynamic flow fields in big data. His innovative method takes advantage of a database approach to shape-based field line modeling, which is expected to substantially improve researchers' ability to visually understand a wide spectrum of flow fields. The new visualization method will turn big data sets (think traffic flows, cash flows, or message flows) into visualizations that make immense data sets digestible. Wang expects his research will have impacts on many fields: shape analysis, visual perception, database organization, game development, and visualization in education.

Wang has left Michigan Tech since winning the CAREER award; he is now an associate professor at Notre Dame.

RESEARCH CENTERS AND INSTITUTES

Advanced Power Systems Research Center (APSRC)
www.me.mtu.edu/research/power
Director: Jeff Naber, Mechanical Engineering–Engineering Mechanics

Advanced Sustainable Iron and Steel Center (ASISC)
www.chem.mtu.edu/asisc
Director: S. Komar Kawatra, Chemical Engineering

Biotechnology Research Center (BRC)
http://biotech.mtu.edu
Director: Keat Ghee Ong, Biomedical Engineering

Center for Agile and Interconnected Microgrids (AIM)
http://aim.mtu.edu
Director: Gordon Parker, Mechanical Engineering–Engineering Mechanics

Center for Computer Systems Research (CCSR)
www.mtu.edu/research/about/centers-institutes/ccsr
Director: Saeid Nooshabadi, Electrical and Computer Engineering

Center for Environmentally Benign Functional Materials (CEBFM)
www.sfi.mtu.edu/cebfm
Director: Gerard Caneba, Chemical Engineering

Center for Water and Society (CWS)
www.mtcws.mtu.edu
Director: Noel Urban, Civil and Environmental Engineering

Computational Science and Engineering Research Institute (CSERI)
www.cse.mtu.edu/projects.html
Director: Warren Perger, Electrical and Computer Engineering

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

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

Great Lakes Research Center
www.mtu.edu/greatlakes
Director: Guy Meadows

I-Enable
Director: Lorelle Meadows

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

Keweenaw Research Center (KRC)
www.mtukrc.org
Director: Jay Meldrum

Michigan Tech Research Institute (MTRI)
www.mtri.org
Co-directors: Robert Shuchman and Nikola Subotic

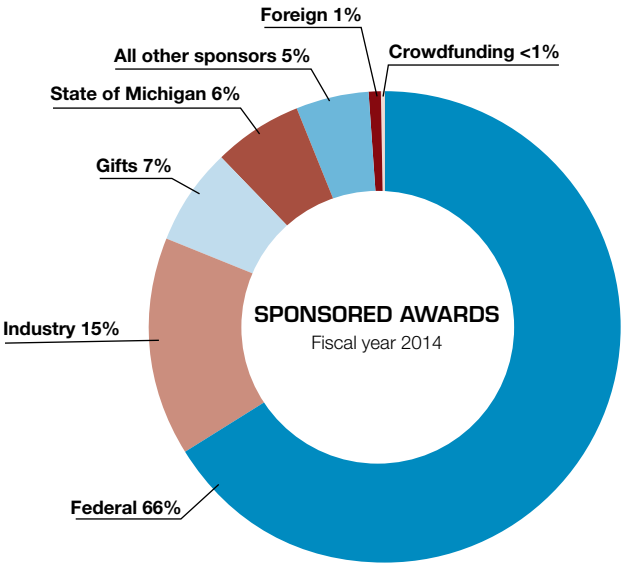
Michigan Tech Transportation Institute (MTTI)
www.mtti.mtu.edu
Director: Ralph Hodek, Civil and Environmental Engineering

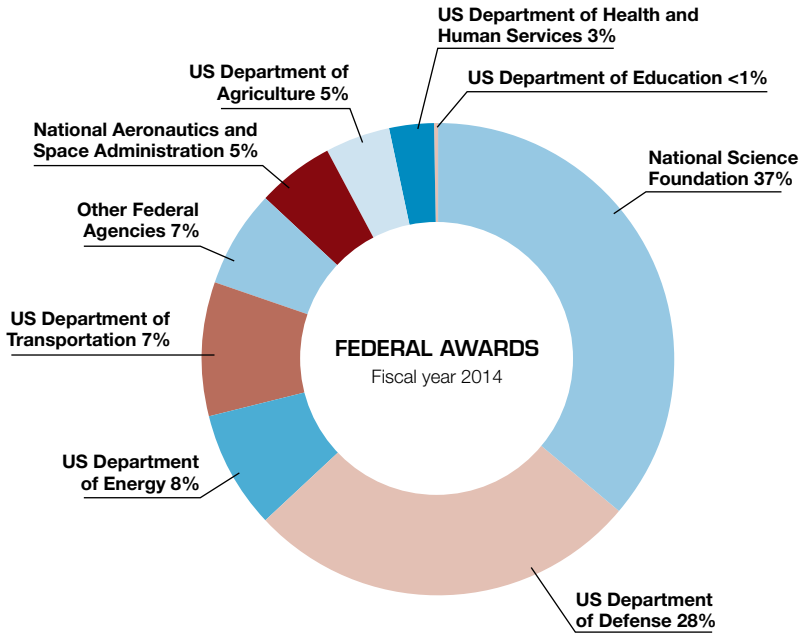
Multi-Scale Technologies Institute (MuSTI)
www.me.mtu.edu/Institutes/MuSTI
Director: Craig Friedrich, Mechanical Engineering–Engineering Mechanics

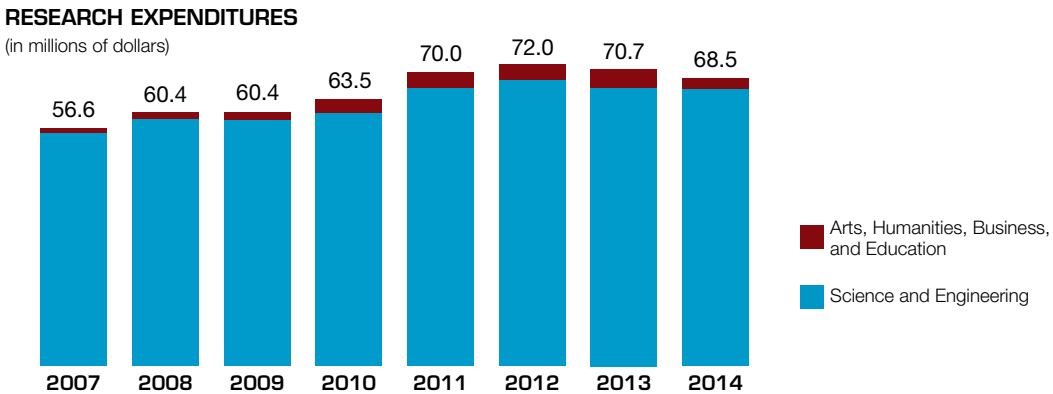
Pre-College Innovative Outreach Institute (PIOI)
Director: Cody Kangas

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

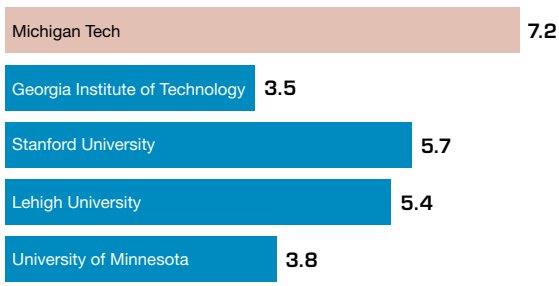
RESEARCH AND SPONSORED ACTIVITY



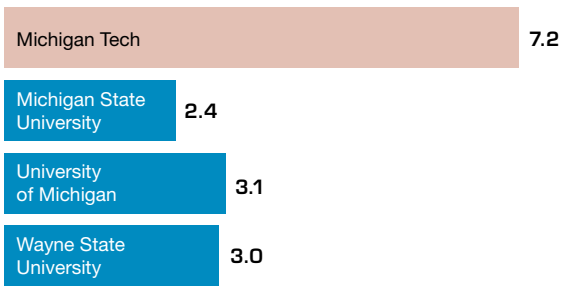




2013 invention disclosures per $10 million of research expenditures
(Compared to benchmark universities)



2013 invention disclosures per $10 million of research expenditures
(Compared to other Michigan universities)



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