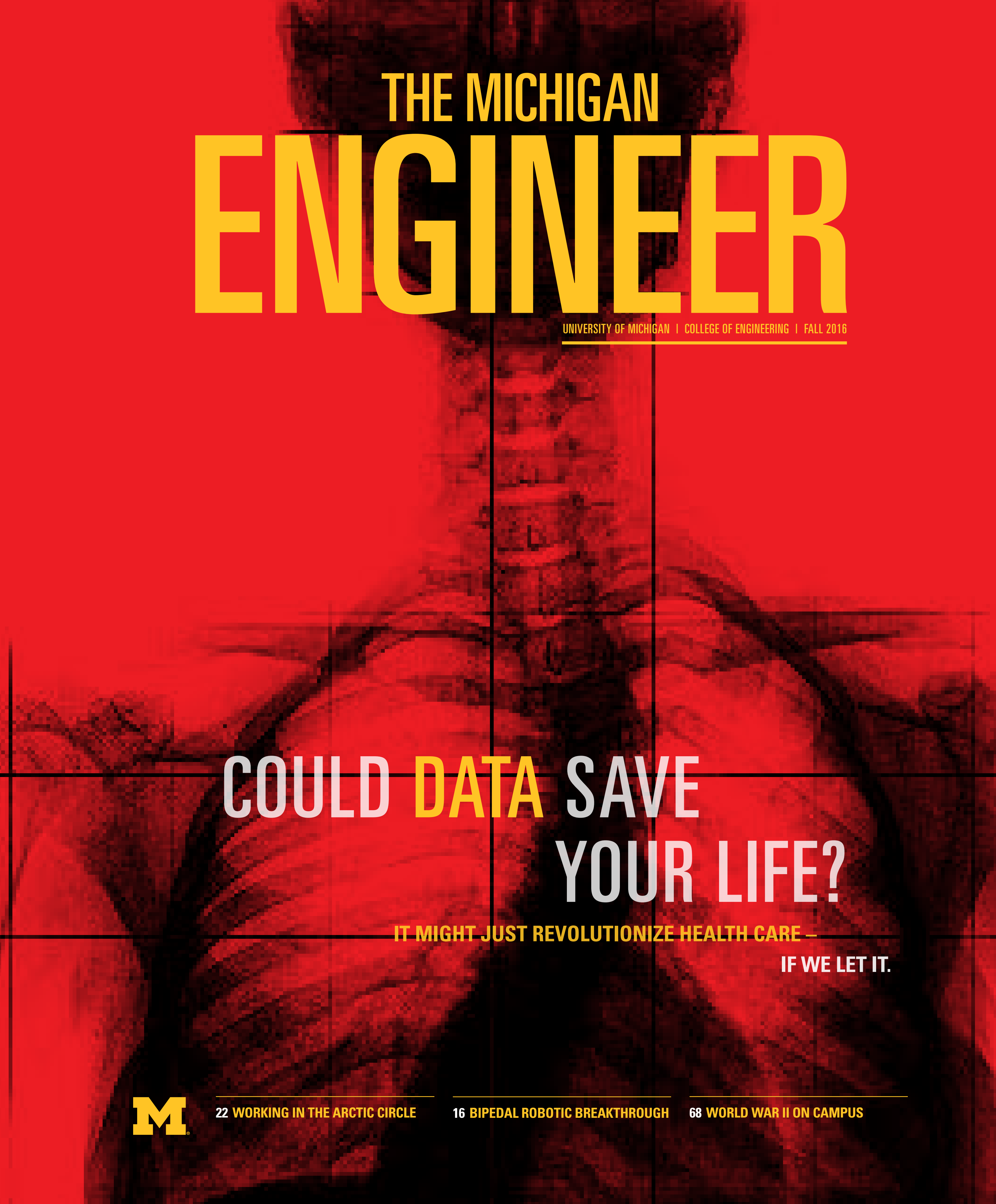

THE MICHIGAN

ENGINEER

UNIVERSITY OF MICHIGAN | COLLEGE OF ENGINEERING | FALL 2016

COULD DATA SAVE YOUR LIFE?

IT MIGHT JUST REVOLUTIONIZE HEALTH CARE – IF WE LET IT.

MODELING AN IMMENSELY COMPLICATED SYSTEM

Jennie Bukowski attempts to use her meteorology training to pinpoint the location of a low pressure system – without any model guidance. “We often laugh at the misconception that meteorologists cannot predict the weather and that models do all of our work for us.” Bukowski, a graduate student in the Climate and Space Sciences and Engineering Department, marked her prediction and then checked the model. “We were spot on!” Score one for meteorology training. You can hear more from Bukowski in a video by scanning this page with the Decoder in the One Cool Thing app.

PHOTO: Joseph Xu

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A U-M alumna reveals her work on top of the world

THE MICHIGAN
ENGINEER

FALL 2016 VOLUME XXXIII, NUMBER 2

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The Michigan Engineer is a magazine for the University of Michigan College of Engineering community, and especially alumni. Its main mission is to engage the College's alumni through content that is thought-provoking, by covering the intersection of engineering, the world and their alma mater.

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UNIVERSITY OF MICHIGAN

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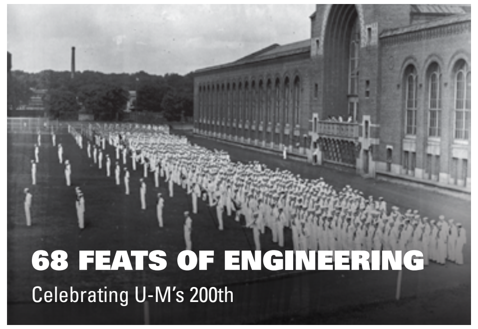

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Alum works toward a vaccine

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READY FOR LAUNCH

Everywhere you look today, engineering is on the rise. Demand for innovations has grown higher as the world faces larger challenges. Students are flocking to the field in droves, creating some of the largest and best classes ever. Partnerships with industry have grown, with more than half of research and development funding in the country happening in this collaborative space. And Michigan Engineering has kept right along with it. We have grown steadily and creatively over the past decade, keeping pace with other top-ranked institutions and producing the best and brightest researchers and alumni.

But we cannot rest. We must continue to push ourselves to be innovative and competitive. For as demand rises, obtaining the funding needed to fuel this innovation is more challenging to secure. And our peers are making advances not only across the nation, but also the globe. There is much work yet to be done.

AS ALEC GALLIMORE BEGINS HIS TERM AS THE ROBERT J. VLASIC DEAN OF ENGINEERING, HE SETS HIS SIGHTS ON THREE MAJOR AREAS OF FOCUS TO KEEP MICHIGAN ENGINEERING COMPETITIVE IN THE GLOBAL RACE TO THE TOP.

3 CLOSING THE GAP

As engineers, it is our charge to innovate and problem-solve. As Michigan Engineers, we consider it our duty to step up and tackle the world's toughest challenges. Our work aims to close the gap – improving the quality of lives for those around the world. We need to be recruiting the best and brightest students, training them through unparalleled education and creating the best engineers the world has to offer. To tackle that charge and help change the world, we must:

- ➔ Foster a culture of respect and inclusion, so that all members of our community will be heard, will get involved and will achieve to their full potential
- ➔ Develop approaches so that all Michigan Engineering scholars can increase their skill level in communicating across cultures
- ➔ Draw resources from a variety of areas, enabling us to create innovative opportunities for students of all socioeconomic backgrounds
- ➔ Improve our curriculum, infusing learning analytics and engineering education alongside hands-on experiences, outreach and global learning
- ➔ Embrace our public university ethos, challenging faculty and students alike to create solutions that will improve the quality of life in all corners of the globe

2 GLOBAL IMPACT

Throughout history, the most influential changes in society, technology and human advances have been disruptive, creating outright fundamental changes in how we existed, communicated, functioned and perceived the world. As Michigan Engineers, we have the capacity to improve the human condition throughout the world by collaborating with top researchers and industries to make breakthrough advances at scale. But we must challenge ourselves to reach those heights, and not to be satisfied with the status quo. To reach a pinnacle of research excellence, we must:

- ➔ Embrace an entrepreneurial, disruptive mindset, developing an ecosystem where people are thinking past incremental advances to major technologies that have the power to change society
- ➔ Invest heavily in research we can lead, influencing the nation's agenda in areas such as robotics, transportation and mobility, stewardship of the planet, healthcare, space systems and manufacturing
- ➔ Focus on our strategic collaborations not only among the College's departments and the University's colleges, schools and institutes, but with institutions, industries, governments and others around the globe to create hubs where disruptive technologies can emerge
- ➔ Secure resources from a variety of funding sources, enabling researchers to work quickly and creatively to solve problems and tackle new challenges

1 EXCELLENCE

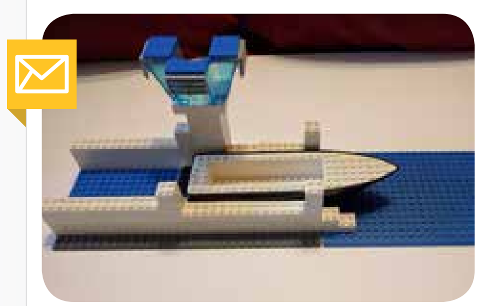
To be a leader is to forge the path ahead, and inspire others to follow. To be the best is to challenge existing confines, and never rest. Leaders and best do both. They push boundaries, inspire generations, lead the charge and are relentless in their quest for excellence. As Michigan Engineers, we must insist upon being the leaders and best, pushing ourselves and our institution to greater heights. To ensure our maximum potential, we must:

- ➔ Develop our faculty as national leaders, ensuring our incentives, recognition and resources encourage and reward excellence, leadership, innovation and risk-taking
- ➔ Encourage our students to achieve the highest education possible, and then work hard to place those alumni in positions where they can lead the nation and the world
- ➔ Secure the critical staff necessary for the College to produce ground-breaking research, secure top grants and support the brightest students in the world
- ➔ Create resources that enable us to aggressively and relentlessly recruit the best faculty and students
- ➔ Provide world-class facilities to support a research and education agenda that promotes and rewards risk-taking

Kid Builders

Our request for Lego buildings, bridges and boats (Xplore Engineering, spring 2016) prompted kids from far and wide to send in photos of their creations. This was one of our favorites.

Have you ever seen those ship-in-a-bottle displays? I've always wondered how they squeeze the whole ship inside the glass bottle. The photo that I'm submitting is of a LEGO pirate ship that I built inside a bottle. It took me two whole days to do it! There were a lot of stops and do-overs. It was fun but required great patience, hard work and "engin"-uity. It turned out pretty well, don't you think?! Thank you for the opportunity to show you my project. You can see a video of how I put the ship in the bottle here: youtube.com/watch?v=AtPI8vI5U1k
Brian K., age 13 (ship made at age 11)
Ann Arbor, Mich.



This is a Lego lock system to allow ships to pass through areas such as the Panama Canal. I think lock systems are amazing in the way they allow boats to pass through areas that would otherwise be impassable.

If I could go to Michigan for engineering school, it would be a happy day for me!
Rhys Hanson, age 11
Evergreen, Colo.

Lights Out

Responses to our article about the possibility of a solar flare knocking out large portions of the electrical grid.

Ever been in a house when the wi-fi resets for 5 minutes? Imagine that multiplied to the nth degree. People will lose their minds. That's what we get for building a world that runs on digital signals and electrons. Suggestion: everyone buy candles.
Jared Lasser

Thank you, MI Engineering, for all you have taught me through my 3x6 digital screen. :)
Lori Jane Mittlestadt

Married to one

Although I am a graduate of the University of Michigan, it was not in engineering. I am fortunate, however, to have married an engineering graduate (BSE '61) that allows me access to your excellent "The Michigan Engineer" magazine, to which I look forward as eagerly as "Smithsonian" and "Discover" magazines, to which I subscribe. I want you to know that for me, "The Michigan Engineer" magazine just gets better and better each issue and I enjoy it from cover to cover. Thank you for such a superior product.
Mary Kathleen Juntunen
(BA '60, education)

Climate change

In reaction to an article about whether society should consider geoengineering as a way to manage the global climate.

Don't even go there! The future of our planet depends solely on how we treat our soil and water resources. Nature bats last.
Jim Snyder

After reading "Is It Time to Get Serious About Geoengineering?", I thought I had been transmitted back in time to the 1970s when all the dire predictions started about global warming/climate change. Although I agree the air pollution was a problem (which "data" now shows has improved dramatically these 30+ years), to continue chasing the carbon dioxide bogey man is just a way to get grant money to study a non-issue. It is more a way for people to line their pockets with money (i.e., Al Gore).

Unfortunately, the very scientists you would quote, who are the doomsayers, have no measured scientific "data" to back up their studies, only computer modeling data. The facts are for the past 15 years of measured data, the Earth has not been warming.

The University of Michigan should be better than printing articles with scare tactics about the end of the world. Let's start to consider the costs in today's dollars on the U.S. and the world, which if we continue down the path of trying to change our climate will eventually bankrupt all of us (even the universities getting paid to promote the myth).
Chris Slupek

A Fond Farewell...

Comments regarding coverage of the end of tenure for Dave Munson as Robert J. Vlasic Dean of the College of Engineering.

So grateful to have worked with Dean Munson and learned from his fine example of leadership, integrity, kindness and excellence. He is a class act.
Ellen Crissey

Can't begin to say how thankful I am to have crossed this man's path. Thank you for supporting me during my leadership journey!
Matthew Nelson

...And a Hearty Welcome

In response to the announcement of Alec Gallimore as the new dean.

Excellent choice. Look forward to working with the new dean, while still sorry to see Dean Munson leaving.
Tony Lembke

I was in his graduate level electric propulsion class and it was the toughest class I ever had.
Jeff Keong

Skunk Works

Thanks for your great article on the accomplishments of Clarence "Kelly" Johnson – I thoroughly enjoyed it. It turns out that my father, Stan Kilpatrick, a mechanical engineering graduate in 1928, although not attaining the fame of Johnson, also made significant contributions in aeronautical engineering through the 1930s to the end of WWII. My dad contributed to the structural designs of such aircraft as the Martin BM-1, B-10, M-130 "China Clipper," PBM-1 "Mariner," and PMB2M-1 "Mars," the Republic P-47, and the General Motors P-75. It would be interesting to read a chronicle of the contributions of all the Michigan alumni of that era to aeronautical development.

Not to diminish Johnson's accomplishments, but it should be recalled that the prototype of the North American P-51, arguably the best U.S. fighter of WWII, was rolled out in a mere 102 days! The P-51 also had then to wait another three weeks before its engine was delivered.

Keep up the good work.
Kerry Kilpatrick (BSE ME '61,
BSE EngMath '61, PhD IOR '70)

I worked with Kelly at the Skunk Works, on the Blackbird in late 1959 and 1960s as an engineer employee of Hamilton Standard, a division of United Technologies. We designed and manufactured the engine air inlet control system and I was responsible for the testing and operation at the secret desert test area at Groom Lake.

Kelly was indeed a remarkable, hands-on type of engineer. Strictly no nonsense. "Do it, damn it" really fit. I was amused once when Kelly showed up at the test site for a "what's wrong with the inlet" meeting in light green coveralls and white "jump" boots. He was another kind.

Another note: I also had a hand in the design test of part of the engine fuel control installed on the engine in Gary Power's U-2. We, of course, had no idea of what was going on. We just made the control Pratt & Whitney asked for.

I had been offered a position in the Skunk Works, which I rejected in loyalty to Hamilton Standard. Had I accepted, I most certainly would have enjoyed work on the Stealth.
Ewart Lockyer, BSME '51

Spring 2016 corrections:

The U.S. Air Corp's Eglin Field was spelled incorrectly in "Skunk Works."

The following were omitted or incorrect in the list of associate deans and department chairs during the tenure of David C. Munson, Jr.: Deans **Doug Noll,** Biomedical Engineering, 2006-12; **Elijah Kannatey-Asibu,** Jr., Integrative Systems + Design, 2007-10; **Khalil Najafi,** Electrical and Computer Engineering, 2008-16; **Lonnie Shea,** Biomedical Engineering, 2013-16; and Associate Dean **George Carignan,** Research, 2005-07, and Research/Graduate Education, 2010-11.

Have something to share? You can use the Decoder in the One Cool Thing app to scan this page and send comments. (See p. 9.) Or email us at MichiganEngineer@umich.edu.

WHAT'S THE CURE FOR MINDLESS WEB SURFING?

ENGI-NERD FOLD-IN

The pervasive condition of "Device Disturbance" is still being studied. The volume of online hooey has become harder to filter – burying useful or interesting information. Michigan Engineering has developed a tool to combat this epidemic. To see what it is, fold in the pages as shown.

FOLD PAGE OVER LIKE THIS!

FOLD BACK SO THAT "A" MEETS "B" A

FOLD PAGE OVER RIGHT B

DOWN THE ROAD, SCIENTISTS HOPE TO ADDRESS THE SOURCE OF WEB-JUNK OVERLOAD.
BUT UNTIL THEN, CAT VIDEOS AND CELEBRITY SCANDALS REMAIN A THREAT.
NOT THAT WE DON'T LIKE AN OCCASIONAL FUNNY CAT VIDEO, BUT COME NOW.

A B

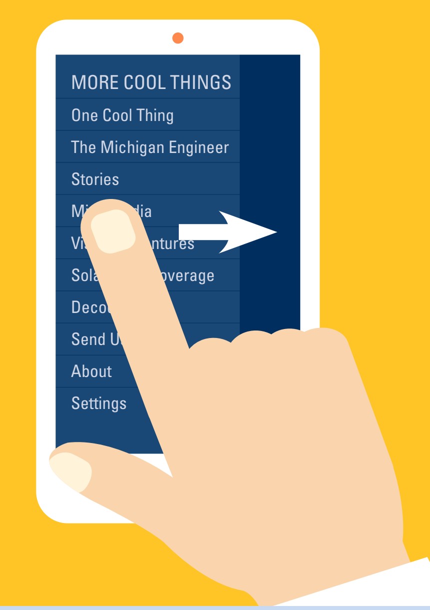
UNLOCK DIGITAL DELIGHTS WITH YOUR DECODER

Throughout the magazine, related bonus content is waiting to be unlocked. When a story mentions the "Decoder," that's your cue. You can also look for this ◌ by the page number.

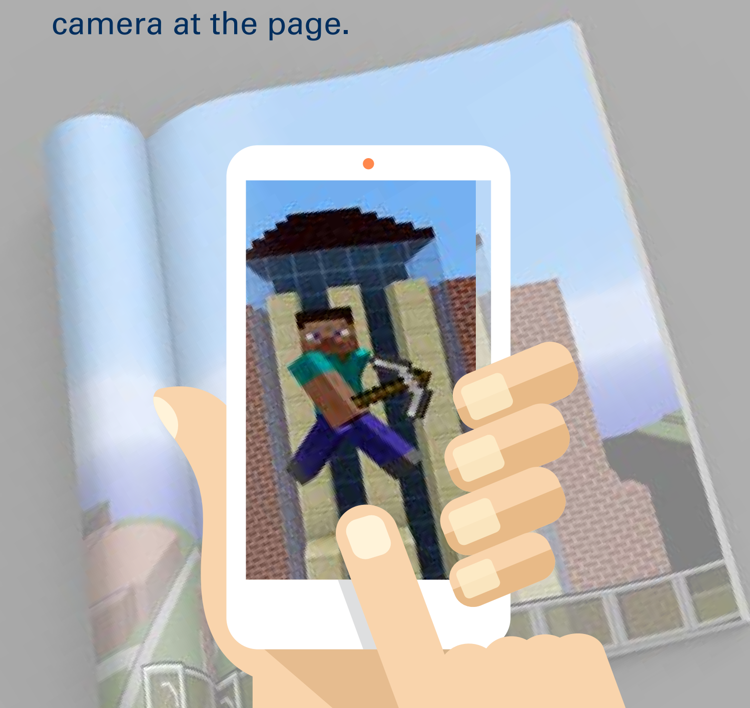
HERE'S HOW IT WORKS.

1. Open the One Cool Thing app on your mobile device.

2. Swipe right ----> to reveal the "More Cool Things" menu.



3. Click "Decoder" and point your camera at the page.



THERE ARE TEN DECODABLE EXTRAS IN THIS ISSUE - INCLUDING A TIMELAPSE OF THE GERSTACKER GROVE TRANSFORMATION; FOOTAGE FROM OF A ROCKET LAUNCH; AND VIDEO OF U-M'S BIPEDAL ROBOT, MARLO, TAKING ON THE WAVE FIELD.

Decoder delights can be found on these pages: Cover, 7, 11, 13, 16, 18, 19, 25, 27, 69, 71, 72, 75.

Just look for the ONE COOL THING by the page number.

Download on the App Store

ANDROID APP ON Google play

PHOTO: Robert Coelius

RANDOM ACCESS

PHOTO: Evan Dougherty

A BETTER FOOTBALL HELMET

Three layers that amount to more than the sum of their parts are at the heart of a football helmet system designed to better protect players' heads. A hard shell and a flexible plastic reflect most of the initial force from a collision. Together these outer materials also convert the frequency of that incoming pressure wave to one the rubbery "viscoelastic" layer can grab ahold of and dissipate by vibrating. In this way the system absorbs the secondary "impulse" from a hit. Current helmets don't. Says Mechanical Engineering Professor Ellen Arruda, "They leave that to the brain."

AN INJECTABLE COMPUTER

This is a picture of a tiny computer in the needle of a syringe. Developed at Michigan Engineering, it measures 10 cubic millimeters. That's 100 times smaller than typical implantable medical devices like pacemakers. Pacemakers require surgery to be put in place. This system might one day be deployable with a simple shot.

Its key innovation is an ultrasmall two-way radio that can broadcast through muscle tissue to a receiver up to a foot outside the body—far enough to send signals to a cell phone in your pocket or on a nightstand while you sleep.

The radio was specifically designed to talk through tissue, said David Wentzloff, associate professor of electrical engineering and computer science and one of the developers.

It doesn't rely on electromagnetic radiation, as typical radios do. It uses magnetic signals. "It's similar to near-field communications, like what's used in Apple Pay, except we have achieved much longer distances," Wentzloff said.

The researchers envision a host of medical applications. Maybe it could provide a noninvasive way for early detection of irregular heartbeats, or monitor glucose for diabetics. One shot could take the place of several every day.

PHOTO: Evan Dougherty

ICE-PROOFING WITH PHYSICS

Engineers made a spray-on coating that repels ice. Its secret is a rubbery texture that relies on a phenomenon called interfacial cavitation, explained Anish Tuteja, associate professor of materials science and engineering. Interfacial cavitation causes a solid material stuck to a rubbery surface to behave differently than if it were stuck to another rigid surface. Even a small amount of shear force can cause tiny waves in the rubbery side, stressing the interface of the materials. Rigid ice crystals slide off with only the force of gravity and a gentle breeze. (Watch it work by scanning this page with the Decoder. Details on p. 9.)

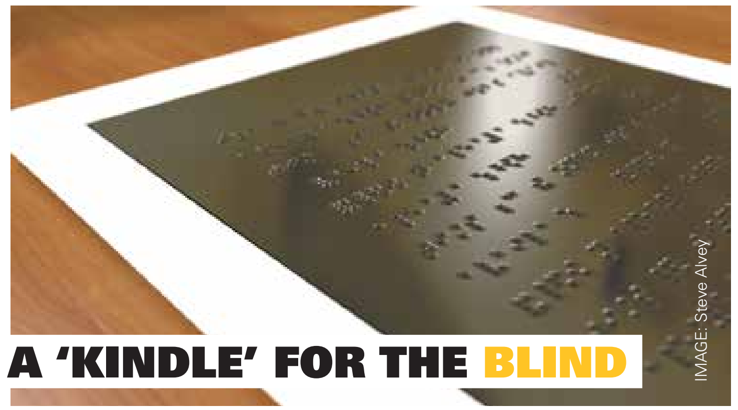


IMAGE: Steve Alvey

A 'KINDLE' FOR THE BLIND

A full-page electronic Braille display is under development by mechanical engineering professors. It would be a dramatic improvement from today's technology that converts computer screen text to raised dots just one line at a time. Its designers say it could expand Braille literacy, an important skill that's been declining with the rise of text-to-speech programs.

PHOTO: Joseph Xu

GUSTS AND GUSTO

Fifth graders worked with undergrads in the student organization BLUElab to design and build a working wind turbine that spins on the roof of their Ann Arbor elementary school. The turbine powers a sign inside and gives the students real-time data about wind speed and direction.

ILLUMINATING TUMORS

Distinguishing cancerous and benign lumps in breast tissue is difficult. Now, a pill containing a dye that concentrates in tumors could clearly light up breast cancers during infrared imaging.

"Screening can potentially catch the disease early in some patients, but false positives can lead to unnecessary, aggressive treatments in patients who don't need them," said Greg Thurber, an assistant professor of chemical engineering. "Our work could help change that."

LONG LIVE THE BUILT ENVIRONMENT

"HOW ABOUT IF WE SET OUR TARGET TOWARDS CREATING INFRASTRUCTURE THAT WOULD LAST 100 YEARS?"

– Victor Li to CNN when the network visited his lab to explore how bendable, self-healing concrete might make bridges and roads more durable. Li is the E. Benjamin Wylie Collegiate Professor of Civil Engineering, a professor of materials science and engineering and professor of macromolecular science and engineering.

A FUNDAMENTAL FUND

The Michigan Engineering Fund helps provide students with the breadth of experiences that the College is known for. In the fiscal year that ended in June, generous contributions added up to **$1.47 million.** Here are just a few things those gifts enabled:

330 STUDENTS STUDIED ABROAD

28 STUDENT TEAMS ADVANCED. ELECTRIC MOTORCYCLE SET TWO WORLD RECORDS.

23 UNDERGRADS RECEIVED SCHOLARSHIPS

19 GRADUATE STUDENTS OBTAINED FELLOWSHIPS

Read about even more programs and activities the fund made possible. Scan this page with the Decoder in the One Cool Thing app. Details on p. 9.

A LONG ROAD TO SUCCESS

A conversation with Matthew Nelson (BSE IOE '15), lifelong learner and National Chair of the National Society of Black Engineers

Matthew Nelson graduated from Detroit's Cody High School in 2002 and began studying at U-M the same year. An illness forced him to drop out in 2004, and after recovering, he worked as a long-haul truck driver for several years. Nelson returned to U-M in 2012 and graduated in 2015. Today, he works as an innovation and new technology planner at the Hyundai Kia America Technical Center in Ypsilanti. He's back at Michigan Engineering pursuing a master's in design science.

Why is being involved in the National Society of Black Engineers important to you?
NSBE gave me a community when I came back to U-M in 2012. It also helped me understand the opportunities that are out there for engineers.

NSBE has a goal of nearly tripling the number of black engineering graduates by 2025, to 10,000. How will you reach that?
I think the goal itself is an important rallying cry that helps us stay focused and opens some new doors on Capitol Hill, in new areas of academia, with corporations and with very big donors. We also need to look at how we support our chapters and make sure we're providing each student with the resources they need to graduate.

Why do you think black students are under-represented in engineering?
A lot of black students aren't exposed to engineering in their early education, so they don't see it as a potential career option. When they can see what an engineering career could do for them four or eight years down the road, it's really powerful.

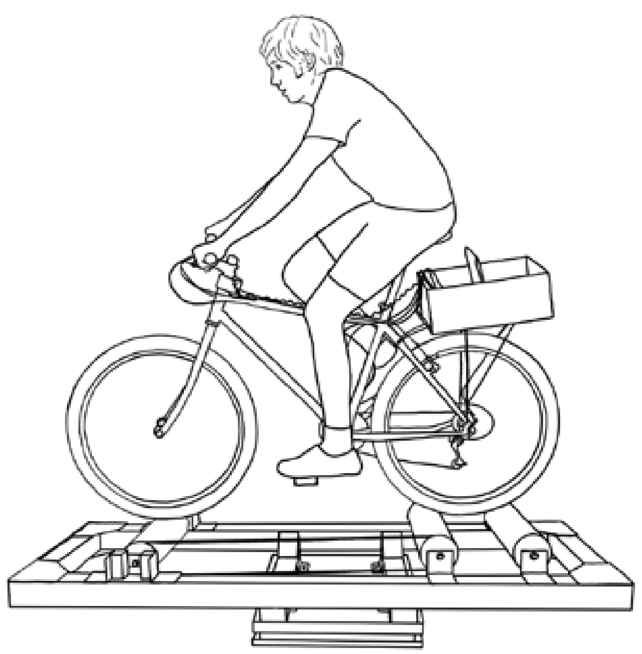
Watch Nelson tell his story – scan this page with the Decoder. (More on p. 9.)

You've traveled a long road to get where you are now. What has it taught you?
Empathy—for other people and the situations they've gone through. Parents, grandparents, the people that cook in the cafeteria or plow the sidewalk. They've all made sacrifices and I think it's important to recognize that.

PHOTO: Evan Dougherty

HOW TO RIDE A BIKE

It's more complicated than you might think



A drawing of a research subject riding the instrumented bicycle on training rollers in our experimental set-up. Courtesy of Stephen Cain.

By Stephen Cain
Research Investigator in the U-M Department of Mechanical Engineering

Humans have been riding bicycle-like machines for close to 200 years. While riding a bicycle can seem simple, the actual control process used by a human rider is still somewhat of a mystery.

Using mathematical equations, researchers have explained how a bicycle without a rider can balance itself and have identified the bicycle design features critical for that to happen. However, the stability – that is, the ability to remain balanced – of a bicycle with a rider is more difficult to quantify and describe mathematically, especially since rider ability can vary widely. My colleagues and I brought expert and novice riders into the lab to investigate whether they use different balancing techniques.

A big part of balancing a bicycle has to do with controlling the center of mass of the rider-bicycle system. The center of mass is the point at which all the mass (person plus bicycle) can be considered to be concentrated. During straight riding, the rider must always keep that center of mass over the wheels, or what's called the base of support – an imaginary polygon that connects the two tire contacts with the ground.

Bicycle riders can use two main balancing strategies: steering and body movement relative to the bike. Steering is critical for maintaining balance and allows the bicycle to move to bring the base of support back under the center of mass. Steering input can be provided by the rider directly via handlebars (steering torque) or through the self-stability of the bicycle, which arises because the steer and roll of a bicycle are coupled; a bicycle leaned to its side (roll) will cause a change in its steer angle.

Body movements – like leaning left and right – have a smaller effect than steering, but allow a rider to make balance corrections by shifting the center of mass side to side relative to the bicycle and base of support.

Steering is absolutely necessary to balance a bicycle, whereas body movements are not; there is no specific combination of the two to ensure balance. The basic strategy to balance a bicycle, as noted by Karl von Drais (inventor of the Draisine, the first bicycle-like machine), is to steer into the undesired fall.

The goal of my colleagues' and my recent work was to explore the types of control used by both novice and expert riders. In our study, novice riders knew how to ride a bicycle but did so only occasionally and did not identify themselves as experts.

We mounted sensors and used a motion capture system to measure the motion of the bicycle (speed, steering angle and rate, roll angle and rate) and the rider's steering torque. A force platform underneath the rollers allowed us to calculate the lateral position of the center of mass relative to the base of support; that let us determine how a rider was leaning.

We found that both novice and expert riders exhibit similar balance performance at slow speeds. But at higher speeds, expert riders achieve superior balance performance by employing smaller but more effective body movements and less steering. Regardless of speed, expert riders use smaller and less varying steering inputs and less body movement variation.

We conclude that expert riders are able to use body movements more effectively than novice riders, which results in reducing the demand for both large corrective steering and body movements.

Our work reveals measurable differences between riders of different skill levels. But the meaning of those differences remains unclear. Ideally, we would like to identify the measurements that quantify the balance performance, control strategy and fall risk of a rider in the real world. With such measurements, we could identify riders at high risk of falling, explore the extent to which bicycle design can reduce fall risk and increase balance performance, and develop the mathematical equations that describe riders of different skill levels.

This is an excerpt of an article that originally appeared at The Conversation. Read the original at myumi.ch/a82qK.

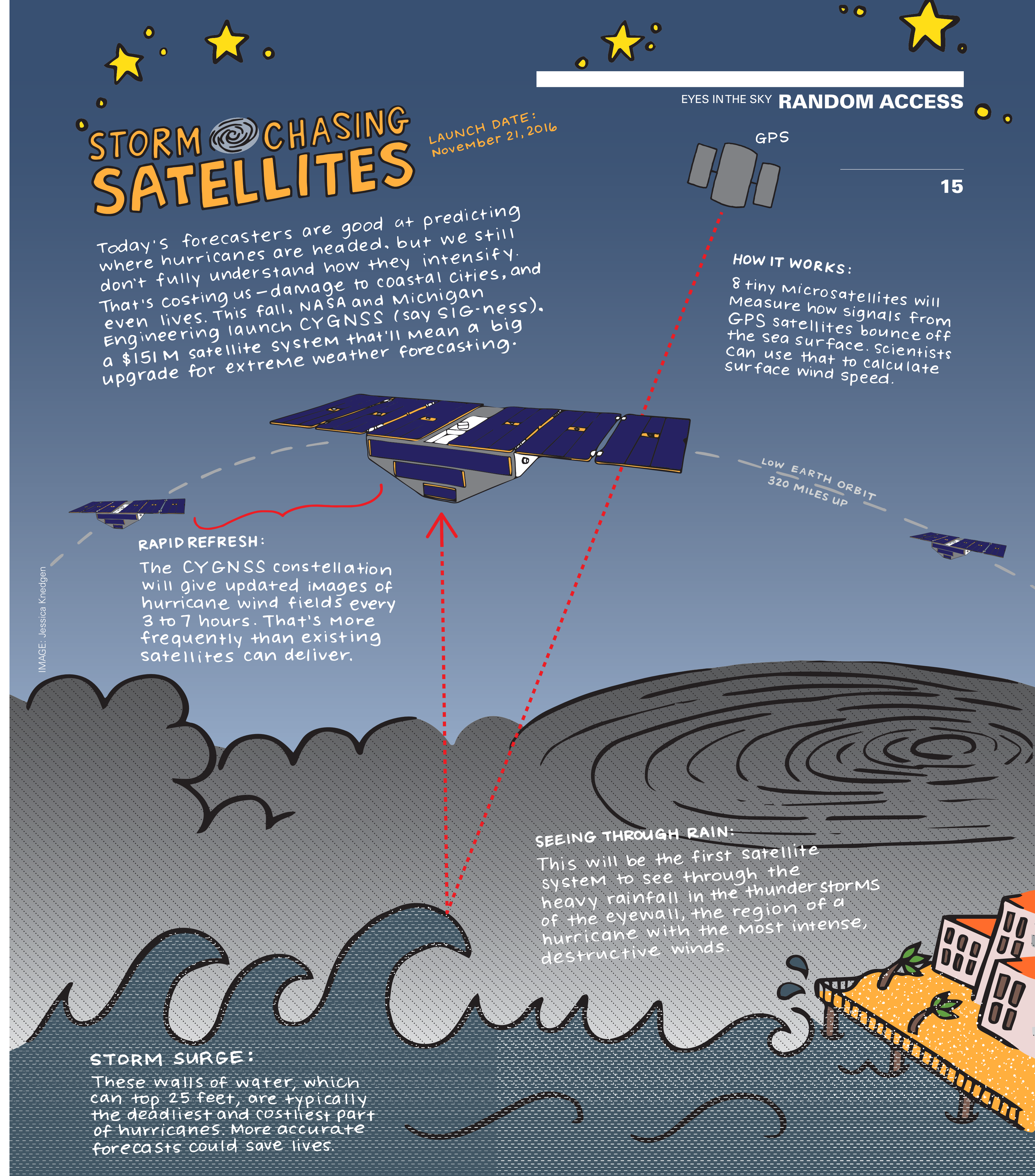
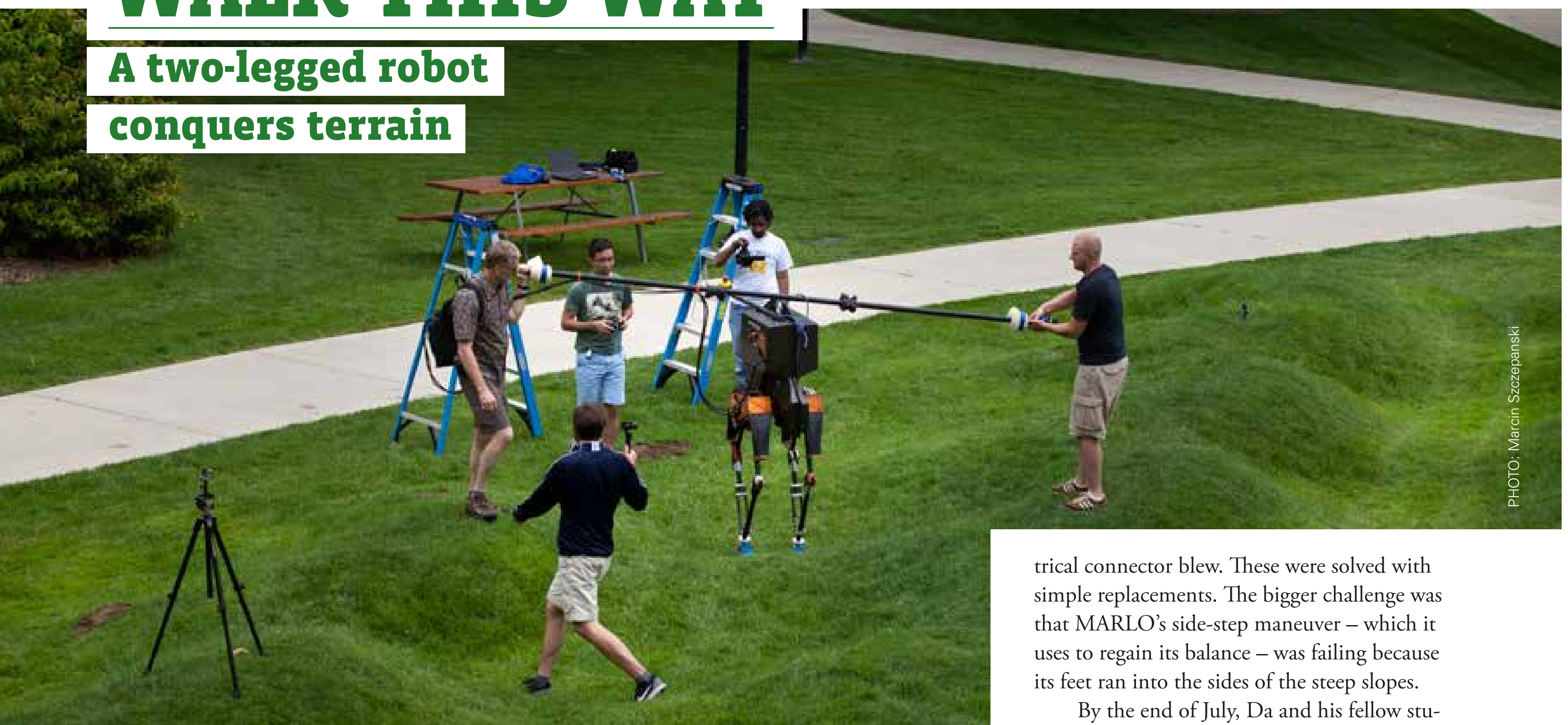


IMAGE: Jessica Kredgen

WALK THIS WAY

A two-legged robot conquers terrain



DOWN STEEP SLOPES, THROUGH THE FOREST, OVER RELATIVELY LOW-LYING PORTIONS OF THE NORTH CAMPUS WAVE FIELD: ADD THESE TO THE LIST OF PLACES MICHIGAN ENGINEERING'S FREESTANDING BIPEDAL ROBOT CAN TRAMP.

MARLO is the first robot in the lab of Jessy Grizzle, that can walk (and fall) in any direction.

MARLO steps blindly without supports, sensing the changes in ground height and adjusting its gait according to terrain and speed. It draws on a library of gaits developed by PhD student Xingye "Dennis" Da.

In early attempts on the Wave Field in June, MARLO broke its legs trying. (See it happen by scanning this page with the Decoder in the One Cool Thing app. Details on p. 9.) The 'bot briefly burst into flames when an electrical connector blew. These were solved with simple replacements. The bigger challenge was that MARLO's side-step maneuver – which it uses to regain its balance – was failing because its feet ran into the sides of the steep slopes.

By the end of July, Da and his fellow students updated the gaits and algorithms to help MARLO navigate the gentler waves between the earthen moguls by integrating the controller for forward-back motion with the one for side-to-side balance. With the team beginning to break up for vacation the following week, they took one last run at the Wave Field and were astonished at MARLO's ability to walk down one of the gullies and back. Emboldened, they took MARLO up one of the big mounds – but it crashed down the other side.

"Our dream is to do the most challenging terrain variation that the Wave Field can offer," said Grizzle, the Elmer G. Gilbert Distinguished University Professor and the Jerry W. and Carol L. Levin Professor of Engineering,

MARLO's feedback control algorithms could help other two-legged robots as well as powered prosthetic legs gain similar capabilities.

A 'DEMONICALLY CLEVER' BACKDOOR

By Kaiyuan Yang
PhD student in the lab of Dennis Sylvester, a professor of electrical engineering and computer science

A minuscule backdoor hardwired into a computer processor rocked the security research world after it was presented at the IEEE Symposium on Privacy and Security this spring and won a best paper award for its authors. Google engineer Yonatan Zunger called it "demonically clever." The backdoor, which fits neatly into the tiniest of empty spaces in the processor, is impossible to detect with current standards. Yet it would give an attacker full access to a computer's operating system. We asked first author Kaiyuan Yang to explain how the team revealed this potential threat.

The hardware Trojan is composed of a trigger and a payload. The trigger monitors the processor and activates the attack payload under very rare conditions, keeping the attack hidden during normal operation and testing.

Evading detection is a critical requirement. This involves more than just staying inactive during normal operation and testing. It also requires hiding from visual or side-channel inspections that measure the processor's power consumption and heat, for example. To accomplish that, a successful Trojan must be controllable by the attacker while minimizing its burden on hardware resources.

Conventional hardware Trojans are digital, and they're power-hungry and difficult to implement. Our analog variant is small, stealthy and effective.

After the chip's design is finished, and while it's being fabricated, we insert our hardware Trojan. It consists of a capacitor and a few transistors wrapped up in a single additional gate. This is known as a fabrication-time attack. A benefit of this particular timing is that the processor has already gone through the most rigorous digital verification stage.

For our Trojan's triggering mechanism, we borrowed the idea of counter-based triggers commonly used in hardware attacks inserted during the design phase, rather than the fabrication phase. Our capacitor acts as a counter, monitoring infrequent events inside the processor. The capacitor siphons charge from a target wire every time that event takes place – every time the wire toggles between digital values.

When the wire toggles infrequently, which is the typical state of affairs, the capacitor voltage stays near zero due to natural charge leakage. However, when the wire toggles frequently, which the attacker can influence, charge accumulates on the capacitor faster than it leaks away. Eventually the capacitor becomes fully charged. When the voltage rises above a threshold, it deploys the payload.

The attacker can control the toggle frequency with software. For instance, the attacker could set up a malicious website that would cause the otherwise infrequent event to occur repeatedly, thus triggering release of the payload.

The payload we deployed was a privilege escalation attack in the OR1200 open source processor. Through our backdoor, we gained control of the processor's privilege bit, which, in the wild would give us control of an operating system. Our experimental results show not only that our attacks work, but that the attacks are not detectable using known defenses.

An incursion like ours would require that an attacker have physical access to processors, which may sound limiting. But state-level actors or malicious employees could represent threats. The trend of smaller transistors, while beneficial for increased performance and lower power, has made fabricating a chip expensive. With every generation of transistor comes the cost of retooling for that smaller transistor. For example, it costs 15 percent more to set up the fabrication line for each successive process node and by 2020 it is expected that setting up a fabrication line for the smallest transistor size will require a $20 billion upfront investment. As a result, most hardware companies outsource fabrication to just a handful of firms, most of which are overseas.

Security research is by its nature an arms race. By exposing this vulnerability, we bring the creativity of the security community to bear on the invention of new defenses.

This explanation contains excerpts from the paper titled "A2: Analog Malicious Hardware." Paper authors are Ph.D. student Kaiyuan Yang, Lecturer Matthew Hicks, Ph.D. student Qing Dong, Professor Todd Austin and Professor Dennis Sylvester, all in the Department of Electrical Engineering and Computer Science.

WELCOME TO THE GROVE

PHOTO: Kelly O'Sullivan

THE AMBITIOUS EDA U. GERSTACKER GROVE PROJECT HAS RESHAPED THE HEART OF NORTH CAMPUS.

The rolling grassy area now includes nearly 180 trees, five rain gardens, sand volleyball and sculptural paths that converge at a central plaza and natural amphitheater. The project's goal was to transform the area from a place people pass through into one where they linger and connect.

Coming soon: Finishing touches that include roughly 300 cylindrical lights (think mini light sabers), and a smart swing set.

The lights will shine in six shades of pink, purple, and blue to illuminate the gardens according to data from a new weather station being installed right in the Grove. The colors' intensity will change depending on what's happening outside. Imagine twinkling lavender during a snow flurry.

The swings, too, have several high-tech features. Their seats will light up and the higher you swing, the brighter they'll shine. In addition, when two people work together and swing in tandem, both will go faster and higher.

"The Gerstacker Grove is one of the most iconic and sacred open spaces on North Campus," said Sue Gott, university planner. "A fundamental goal was to create a destination spot for all members of the University community."

The Grove is an idea nearly six years in the making. (Check out a timelapse of its construction. Scan this page with the Decoder in the One Cool Thing app. Details on p. 9.) It makes its debut on the 20th anniversary of the iconic Ann and Robert H. Lurie Tower. Both the anniversary and the official Grove unveiling will be celebrated this October during homecoming.

GO BLUE... AND BEYOND

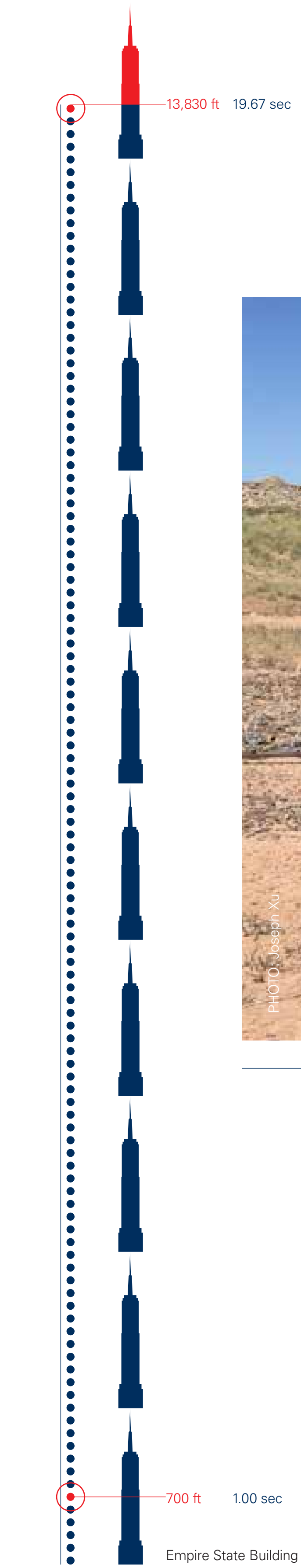


PHOTO: Joseph Xu

MAX APOGEE:
13,830 FT

OUTER DIAMETER:
6.7 IN

THRUST:
500 LBS

MAX VELOCITY:
703 FT/SEC

HEIGHT:
12 FT

HOURS BEFORE SUNRISE ON A FRIDAY THIS SUMMER, 14 MICHIGAN ENGINEERING STUDENTS CAREFULLY POSITIONED THEIR CUSTOM-BUILT ROCKET ON A LAUNCH PAD IN A DESOLATE CORNER OF UTAH.

Three years and countless hours of modeling, testing and prototyping had led to this moment. Finally, it was time to launch The Great Emancipator. (The students traditionally name their rockets after U.S. presidents' nicknames.)

More than 50 teams from around the country had made the same rocket-fueled pilgrimage. And when the dust settled, the Michigan Aeronautical Science Association earned second place in the advanced category at the 2016 Intercollegiate Rocket Engineering Competition. (Watch the launch. Scan this page with the Decoder. Details on p. 9.) Setting a team altitude record, the nitrous hybrid motor rocket was MASA's tallest, heaviest and most powerful (in terms of its total motor impulse) to date.

"A fully student-built rocket engine is a rare thing, and the fact that we successfully launched it is incredible," said team member and electrical engineering student Nicholas Sterenberg. "I can't explain how proud I am of the team, and all that we have accomplished. Our launch was great, but we already have plans for future endeavors."

FOND (YET STINKY) MEMORIES

Some people will remember walking across the Diag for the first time, or have fond memories of pulling an all-nighter in the Dude or the Wilson Center. For some, spotting sneakers hanging overhead on Church Street or Catherine will ring a bell. This practice is apparently common on college campuses. But in Ann Arbor, it's generally a sign that someone has been celebrating – maybe the end of the school year (or just the end of the week).

PHOTO: Joseph Xu

FROM THE EDGE OF THE ARCTIC

At the top of the world, the climate is changing fast. A Michigan Engineer tracks the planet's vital signs.

Story by: Nicole Casal Moore
Photos by: Marcin Szczepanski

The Dalton Highway cuts through the Brooks Range at Atigun Pass, about 40 miles south of Toolik Field Station. The narrow, winding road has been featured on the History Channel's reality show, Ice Road Truckers.

COLD, WHITE WILDERNESS SURROUNDS TOOLIK FIELD STATION, A WORLD-RENOWNED ARCTIC RESEARCH OUTPOST DEEP IN ALASKA'S INTERIOR.

It's a cloudy March afternoon with a wind chill of -20°F as scientist and Michigan Engineering alum Brie Van Dam treks up a mountain that overlooks the station.

In some directions, it's hard to tell where the ground ends and the sky begins. In others, frosted ridgelines jag across the horizon. The only signs of civilization are the distant camp buildings and the single road that cuts a dirty path through the snow. The closest villages along it are two hours away.

Van Dam (BSE AOSS '07) is in the midst of a five-hour excursion – most of it on snowshoes – to document the ground cover at a plot near the top. Tiny icicles are crystalizing on her lashes. Condensation from her breath is solidifying on her scarf. While she's weathered lower temperatures, she knows not to stay still for too long. That's when the chill can get dangerous.

Harsh and frozen: the Arctic's been this way for most of the past 55 million winters, including, of course, the most recent 10,000 during which humans, enabled by Earth's modern climate, have flourished and multiplied to seven billion. The region's store of ice, both on the sea and land, stabilizes the planet's temperatures in a host of important ways. You might think of it as the mortar in the foundation of the climate as we know it.

But the foundation is cracking. The Arctic is warming faster than any other place on Earth. Not only is it heating up more rapidly, the pace of change is speeding up. Melting ice is melting more ice and touching off tangent cascades along the way: Permafrost is thawing and freeing more greenhouse gases. As the northern waters warm, climate-regulating currents in the ocean and air are slowing. All while the seas are rising. The consequences of Arctic warming are rippling across the globe, and they're on track to keep escalating exponentially.

"It's easy sometimes as a scientist to look at things through the science lens of: 'Oh, wow, what a cool time to be studying the Arctic because the Arctic is changing so fast right now,'" says Van Dam, who manages the station's Environmental Data Center. "But when you look at that through more of a human lens, it becomes honestly really terrifying."

Van Dam faces these facts every day in her work documenting climate change from its epicenter, year-round. She's a member of the skeleton crew that stays at the station through the coldest months. The winter yields pivotal insights, and the most recent was the warmest in recorded history.

In the snowpack samples she gathers, in the wing prints of the local birds and even in the patterns the wind makes on the powder, the snow, Van Dam says, tells stories. She is paying close attention. Her monitoring work is, pixel-by pixel, helping to paint a climate picture that you have to stand way back to see.

SCIENTIST AND STEWARD

Van Dam has been connected to the snow for much of her life. As a child, she and her brother built igloos in Michigan winters. As a doctoral student at the University of Colorado at Boulder, she studied how sunlight reacts with pollutants in the spaces between fallen snowflakes.

She first set foot in the Arctic while she was an undergrad at U-M. She spent a summer in Alaska's wilderness through an outdoor education program. During that trip, she helped rescue a fellow student from a glacial crevasse – and she fell in love with the far north. She connected with its raw nature, its dangers accompanied by stark beauty and otherworldly light.

"I did really 'fall in love' with the landscape," she says. "Love is a verb, right? It's something that we do, and so loving the landscape, for me, means really being a part of the environment on a personal level."

In addition to her role as a scientist, Van Dam is a steward of the world around her.

When she's not at the field station, she lives in a cabin in Fairbanks that has no running water. Such set-ups are relatively common in interior Alaska because the frozen ground is difficult to plumb through. She gets her water for drinking and washing dishes and clothes by refilling giant jugs in town once a week. The outhouse is out back and, in Van Dam's case, the shower's at work in her local office. While it's not the most convenient approach, it's easy to conserve when you don't have a tap.

Van Dam's freezer is stocked with the meat of a caribou she killed in the Brooks Range. She and a hunting partner skinned it, quartered it and hauled it home on a sled.

"I showed up to my Fairbanks office still smelling of caribou blood," she recalls.

That animal, and wild salmon caught by a friend, will be her protein for most of the next year. Industrial meat production is a major carbon emitter and as much as she can, Van Dam opts out of that cycle.

"The idea that our species – that really, my actions and choices – are having an irreversible impact on the planet kind of blows my mind sometimes," she says.

On the mountain overlooking Toolik Field Station, which is funded by the National Science Foundation and part of the University of Alaska Fairbanks Institute of Arctic Biology, she stops at the top in sub-zero temperatures to gather data. About once a month, she takes pictures of landscape conditions at several plots for researchers studying two tundra plant species. They're documenting how climate change is affecting the global range of a particular moss and an alpine herb.

She could take a snowmobile the two miles to the base and back, but she prefers to cross-country ski or snowshoe, knowing that the only carbon dioxide she adds to the atmosphere comes from her own breath. It's a long journey for a set of photographs. But it's an important one.

Winter is the longest and most critical season in the Arctic. It's when ice platelets on the sea coalesce until stretches of ocean are frozen over. It's when snowpack accumulates. In some places, the new layers add girth to glaciers. In others, snow insulates the ground, preventing soil from re-freezing and losing the heat it collected in summer.

Winter is also the station's sparsest. Though more than 100 projects are typically underway at any given time, almost none of the researchers involved are able to get there for regular observations. So Van Dam stands in, looking in the nooks and crannies for small signs of the bigger changes afoot. She's a crucial set of eyes. (Scan this page with the Decoder in the One Cool Thing app to see a video of Van Dam explaining the challenges of instrumenting the Arctic. Details on p. 9.)

POLAR ICE AND THE GLOBAL THERMOSTAT

The Arctic is a place of extremes and opposites – frozen but melting, vulnerable but hardy. It's the 7 million square miles north of the Earth's 66th parallel where the sun doesn't set on Midsummer Eve or rise on the winter solstice. It's an ocean ringed by the coasts of eight countries.

The top of the world is feeling the heat much more so than the Antarctic, where the ice is thicker and higher, and a frigid ocean current encircles the continent, keeping warmer waters at bay.

Comparatively, the sea ice and snowpack up north are thin. And the records here are breaking as fast as that ice is.

Month by month, 2016 is on track to be the warmest year on record. Globally, temperatures have exhibited the greatest departures from average since recordkeeping began in 1880, according to NASA. January was nearly

Brie Van Dam at work in her Fairbanks office with Clyde and Vilde, her rescued, retired sled dogs.

two Fahrenheit degrees warmer than average, February more than that. But over the Arctic, the anomalies during those two months were staggering – more than 7.2°F.

"The changes occurring in the Arctic are nothing short of startling," says Jennifer Francis, a climate scientist at Rutgers University. "They encompass all aspects of the system."

Francis calls the shifts "disturbing," and not just for the region itself and the 4 million people who live here.

"What happens in the Arctic doesn't stay in the Arctic," she says. This is true in many ways, but in particular, the melting of ice and snow cover is destabilizing a vital mechanism in the global thermostat. Snow bounces back 90 percent of the solar energy it's exposed to. Sea ice reflects between half and 70 percent. But the ocean returns only 6 percent. It absorbs the rest of the heat like blacktop in the summer. So the more snow and ice that melt, the more heat the newly exposed surfaces hold onto, which leads to higher air temperatures – and more melting.

READING THE SNOW

It's a frigid March morning outside the Environmental Data Center – one of the high-tech trailers on the 30-acre campus of the field station. Van Dam is packing for a day of measuring the snowpack. She loads her tools onto a utility sled. They include an ultra-precise ruler, a coring column, a notebook and a pencil (because pens can get temperamental in these temperatures). She secures it all with bungee cords.

> I THINK THAT THE BIG SURPRISE FOR THOSE OF US WHO STUDY ICE IS THAT IT TURNS OUT WE'RE TALKING ABOUT SHORTER TIME SCALES TO MAKE SIGNIFICANT CHANGES.
>
> \- Jeremy Bassis, associate professor of climate and space sciences and engineering

She steps into cross country skis, reaches down to the sled's rope, lifts it up and clicks the harness around her waist. Poles in hand, she muscles off, her purple shadow leading her into the white expanse, skis squeaking against the snow.

Today's work takes Van Dam a mile and a half from camp to what she calls vegetation phenology plots – designated spots where she monitors the environment through the seasons. In the winter, she measures the snow, including its depth, density and liquid water content. Researchers from all over the world with projects at the station can use the data Van Dam gathers to put their own findings into context.

This kind of routine information gathering is "vitally important to understanding the behavior of the climate system," writes Henry Pollack, a U-M emeritus professor of earth and environmental sciences in his climate history and cautionary tale, A World Without Ice. "But this type of scientific work is not glamorous."

When Van Dam and her sled arrive at the first sampling site, she throws a down jacket on top of her other layers. She won't be as active here as she was on her commute, and temperatures are in the teens. A warm winter is relative here.

Before she gets to her task, she pauses to point to a trail of bird footprints.

"If you look right here," Van Dam says, "the ptarmigan was walking walking walking, and you can actually see the wing prints from when it took off. Isn't that beautiful?"

They were scattered all over the sparkling surface, deep divots and quotation mark grooves becoming shallower and fewer as the birds took flight.

"One of the things I really love about snow is it tells you stories. You can sort of read it."

She begins her more rigorous reading by measuring how deep the snow is. She dips the scientific ruler into the snowpack at 50 different points and records the millimeter markings in a journal. Moving on to density measurements, she unpacks a hollow metal tube with a T-shaped grip called a "Federal corer."

She drives it in, twists it, and lifts out a snow plug. She pours the contents into a plastic bag. Then she does it again. And again. She gathers 20 cores at this location.

Van Dam gears up and heads over to the frozen Toolik Lake, just south of the first sample site. She measures more snow there. And when she's done, about three hours after she had left the station, she loads 25 bags of snow onto the sled, attaches the harness and swishes her skis across the solid lake surface to tow it all to the data center.

When she gets there, Van Dam weighs each sample, then all of them together. Eventually she appears in the doorway of her office trailer with a bag of snow held high. "You see all that work?" she asks.

She dumps the contents into the growing mound out front and laughs. The data she needed from those ice crystals is in digital form on her computer.

Once she did the math, the snowpack of the station turned out to be a bit shallower than it's been in recent years. The average depth of about 10.6 inches is the lowest since her office started gathering data in 2012. Granted, that's not a very long historical record, but one day it will be. Researchers will refer to it as they work to understand what used to be, and how different the climate of the 2010s was from the climate of the decades to come.

In addition to helping scientists identify change in the climate system, ongoing monitoring can also raise red flags that researchers' projections need to be revised. That's key as humans plan to adapt. (Decoder video: Van Dam makes snow measurements and explains her work.)

THE TIPPING POINT AND THE ICEBERGS

One recent revision is the estimate for how quickly the ice will melt. For a long time, scientists have had a broad understanding of how melting snow and ice would exacerbate climate change. What they didn't realize was that ice dynamics are remarkably complex, and the feedback loops don't always lead to gradual change.

"Just as a small tree branch will bend a little when a boy steps on it, and bend a little more when his (friend) joins him, everyone knows there is a limit to the loading beyond which the branch no longer bends – it snaps," writes Pollack, who conducted research at Toolik Field Station in the '90s.

Three feet of sea level rise by 2100 is the Intergovernmental Panel on Climate Change's standing estimate. But ice has been turning to water on both poles much more abruptly than climate models predicted. Ongoing monitoring from satellites has brought this to light. And Jeremy Bassis's work has helped explain why.

For a long time, ocean rise estimates have ignored a phenomenon that accounts for roughly half of the mass lost in ice sheets. That neglected process is iceberg calving – bergs detaching from land-bound ice and glaciers. It's been left out because it wasn't clear what factors were involved, explains Bassis, an associate professor of climate and space sciences and engineering at U-M.

Bassis has identified the physics at the heart of iceberg calving. Now researchers are relying on his equations to more accurately simulate how soon we can expect the oceans to lap at our coastal roads and porches.

Newer estimates say three feet this century is an unlikely minimum. A better bet is twice that – six feet in the next 85 years followed by

Van Dam climbs a 15-foot tower to swap out the SD card of a camera that takes a photo of the valley every day at noon.

a foot per decade. Compare that to the current pace of about an inch per decade, a pace that's already causing Miami Beach to spend up to $500 million on a network of walls, raised roads and pumps to fight periodic flooding at high tides.

"I think that the big surprise for those of us who study ice is that it turns out we're talking about shorter time scales to make significant changes," Bassis says. "We used to think on the order of 1,000 years. Now the estimate is within centuries, but we can't rule out decades."

It's happened before, Pollack says. Scientists can tell by studying fossils of coral reefs that some 120,000 years ago, during the end of a warm interval in between Ice Ages, the seas rose eight feet in 50 years.

The cause of this flash melting, Pollack says, was "extremely rapid sloughing of ice into the sea." Recently, both Greenland's and Antarctica's ice sheets and glaciers have been surrendering at alarming rates.

That's all to say that snow and ice seem to be foreshadowing dramatic turns in the climate story.

PERIL IN PERMAFROST

It's true both above and below ground. Though the dirt at Toolik Field Station is covered with snow today, researchers – supported by Van Dam – are examining how the soils are reacting and contributing.

In a hooded parka and thick cargo pants, Van Dam kneels by the station's weather sensors. She needs to replace some equipment, and it's buried in snow.

Her task is to swap out an electrical box and two ultraviolet light sensors, as well as the wires that connect them through a protective pipe, which is also buried. Nothing's broken. She just has to send it all to the manufacturer to get it calibrated periodically.

With a shovel, Van Dam carefully cuts into the snowpack around the electrical box. Then she hoists up blocks of frozen snow and tosses them behind her.

"I don't want to just dig it all out with the shovel," she explains, leaning shoulder-deep into the drift. "I have to make sure I don't cut any wires."

The weather station does a lot more than tell the locals how cold it is. The ultraviolet sensors, for example, are helping U-M researchers study how sunlight affects permafrost – a thick layer of frozen soil and plant matter under the snow Van Dam is excavating.

Permafrost comprises about a fifth of Earth's land area. Though it sounds more enduring, it technically refers to soils that haven't thawed for at least two years. Much of it, especially in the coldest parts of the world, is far more ancient. Alaska holds a Russian variety called yedoma. It formed during the most recent Ice Age more than 12,000 years ago when glaciers overtook green valleys and grasslands.

Guess what: It's also thawing much faster than scientists expected. Not only is this a problem for the infrastructure on top – think oil pipelines, roads and homes – it's another global warming consequence that leads to more of the same.

AN ICE-FREE NORTHERN HEMISPHERE, WITH NO SEA ICE COVERING THE ARCTIC OCEAN AND NO ICE SHEET ON GREENLAND, IS A POSSIBLE CONDITION OF THE MODERN CLIMATE SYSTEM.

-Henry Pollack, professor emeritus, U-M Department of Earth and Environmental Studies

The icebound plants, which were covered by dirt at the pace of about a meter per millennium, are stores of carbon. When they finally defrost, microbes in the soil will break them down. Their decomposition will release greenhouse gases. And a lot of them.

The Arctic's permafrost today holds more than twice as much carbon as our atmosphere already contains, says Rose Cory, an assistant professor in the U-M Department of Earth and Environmental Sciences who leads the project that's using the UV sensors. She is studying the role sunlight plays in how organic carbon decomposes.

Depending on how quickly that carbon is released, it could have a big warming impact.

At the same time, policymakers base carbon dioxide limits on climate models that don't take permafrost thawing into account at all.

"Only recently have we gotten an estimate of how much carbon there is in permafrost. The knowledge hasn't been incorporated yet," says Ellen Dorrepaal, a plant ecologist at Umeå University in Sweden whose project Van Dam has also assisted with.

New studies from just this year have called attention to this. Thawing permafrost is projected to become a significant source of carbon in the atmosphere by 2100.

STANDING WAY BACK

We live on a planet.

That's how U-M associate professor Bassis responded when asked about the role the Arctic plays in the shifting climate. He wasn't being facetious. Earth is a self-contained sphere, but that's easy to forget if you're not a climate researcher.

"We think of the Earth as a system, as this big complex system. The Arctic is one component of that system," Van Dam says. "And all of us who've learned a bit about engineering understand that in general you can't change one component of a system without having an impact on the entire system."

That's especially true when that changed component kicks off self-reinforcing loops, feedback cycles that knock the entire system out of equilibrium.

In addition to the planet's mean temperature, carbon dioxide levels are spiking faster than ever before. At more than 400 parts per million today, the atmosphere holds more of the gas than at any point in known history. It likely holds more than it has since a warm period roughly three million years ago in a geological epoch known as the Pliocene. Then, says geologist Pollack, the seas may have been 100 feet higher, and shorelines 100 miles inland. All of Florida was likely under water. Scientists aren't sure what brought about the Pliocene climate. While high carbon dioxide levels played a role, their cause is unclear. Changes in ocean and air currents likely contributed to the warmth, and its eventual end. Scientists believe it came to a close some 300,000 years after it started due to continental movement that shifted ocean and air currents.

"The overarching lesson of the Pliocene is sobering:" Pollack writes, "An ice-free Northern Hemisphere, with no sea ice covering the Arctic Ocean and no ice sheet on Greenland, is a possible condition of the modern climate system."

Earth has been through something similar before. But humans haven't.

"It's not just climate change. We're having an impact on our water, air and wilderness preservation," Van Dam says. "All these things are related and extremely important. That gives me a great sense of responsibility to use my training in engineering and sciences to try and have a positive impact, not a negative one… And sometimes that sounds like bullshit, but most of the time I feel like it's important to at least try."

U-M 2015:

422> INVENTIONS
160> PATENTS

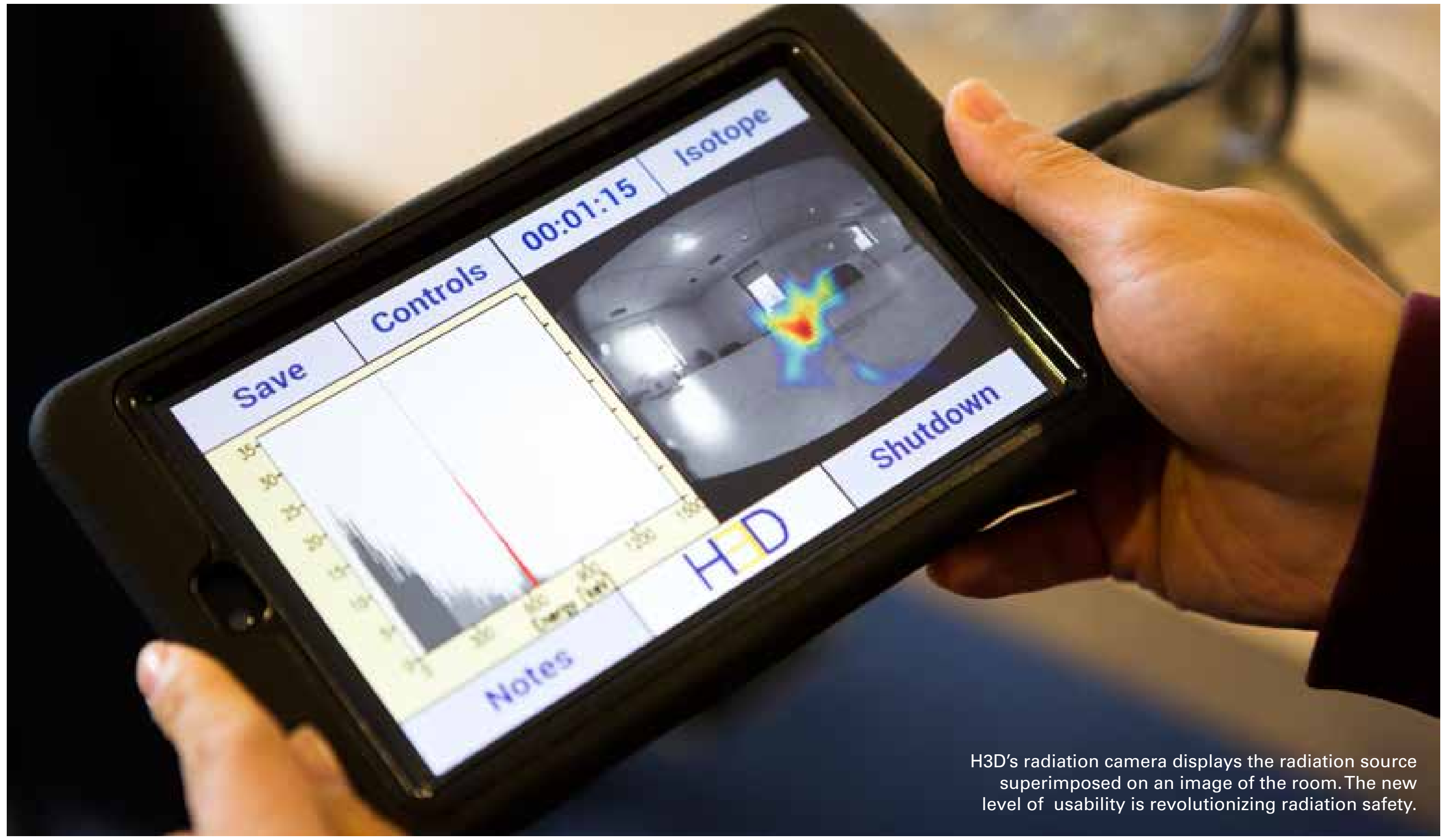
STARTUPS
19

FINISH LINE

INNOVATION IS FOR FINISHERS

HOW DO RESEARCHERS MOVE AN IDEA TO THE MARKETPLACE? MORE AND MORE ARE HOPING STARTUPS WILL HELP THEM GO THE DISTANCE – AND UNIVERSITIES ARE HELPING THEM GET THERE.

Story by: Kate McAlpine



H3D's radiation camera displays the radiation source superimposed on an image of the room. The new level of usability is revolutionizing radiation safety.

PHOTO: Joseph Xu

Pacemakers, insulin, Breathalyzer tests, computers and MRI machines are university developments. All of these technologies were so obviously important that they were adopted long before universities began making an effort to get laboratory inventions out the door. But many more sat on the shelves.

One of these was a plan for a radiation camera that was capable of overlaying an image of the room with a map of radiation sources. Initially proposed in the mid-1990s by Zhong He, a professor of nuclear engineering and radiological sciences at U-M, it might have been ready to deploy in the areas around Fukushima following the disaster in March 2011.

But the companies that were theoretically capable of rapidly developing such a camera through the 2000s couldn't do it. He estimates that $50 million in grants and contracts went toward room-temperature radiation cameras, but no one realized the potential of cadmium zinc telluride crystals, which are at the heart of He's camera.

"Our conclusion was that we cannot count on other companies to work on the technology," He said. If his team wanted to see these cameras in the hands of nuclear safety professionals, they would have to start a company.

So in the fall of 2011, He began a journey that more and more faculty around the U.S. are making—from inventor to innovator. These entrepreneurs are helping universities to deliver on the promise that taxpayer-funded research will drive economic growth, and lately, universities are doing much more to help them succeed.

"I NEVER STARTED OUT TO BE A BUSINESSMAN. BUT IT'S SO FANTASTIC TO BE ABLE TO LISTEN TO SOMEONE AND SOLVE THEIR PROBLEM."

ENTREPRENEURSHIP: A NEW HOPE

Universities weren't always going on about innovation, and professors weren't always ready to bring their own ideas to market. Until recently, academics typically took a dim view of business.

"In the old days, faculty members didn't want to do a startup because they would be looked upon as someone who had gone over to the dark side," said Fred Reinhart, a senior advisor for technology transfer at the University of Massachusetts Amherst and former president of the Association of University Technology Managers (AUTM, pronounced "autumn").

But there was another factor as well—faculty inventors and universities didn't always have the rights to their own inventions. The government bodies that provided funding for research typically retained the rights to the results. That didn't work out particularly well: Only about 5 percent of government-patented research discoveries were successfully licensed to companies to develop into products. So in 1980, Congress passed the Bayh-Dole Act, which gave inventors, universities and laboratories intellectual property rights.

That kicked off the academic foray into commercializing research findings. It started with tech transfer offices, which popped up at most major research universities across the U.S. within a few years. Reinhart joined the U-M office in 1985 as a newly minted Wolverine MBA. When he started out, it was just him, a licensing professional and two lawyers. "We were like pioneers. We were making our own road," said Reinhart.

The first 20 years were mostly about licensing: patent the idea, give it to an existing company to develop and market, and then collect the royalties. This route didn't take the faculty away from their research and teaching duties. But it also left many technologies to languish in what tech transfer professionals call the "valley of death," which lies between the exciting lab-scale results and a working prototype. Licensing based on lab results requires great faith in the invention and confidence in the company's own ability to make it work. The distance to the finish line—and the obstacles in the way—are uncertain.

When He initially patented the underlying technology for his radiation camera in 1998, the tech transfer office couldn't make a match for it. It was in the valley.

THE WALK THROUGH THE VALLEY

But professors and their recent graduates and post-docs often have the confidence and skill necessary to make it through the valley of death. It's their discovery and they have clear ideas about its potential and limitations, so the technological challenges don't look so scary.

In the late 1990s and early 2000s, He wasn't quite ready to take that gamble. There was more he could do in his lab. But in 2011, he and his graduate students realized it was time.

"The original purpose of setting up the company was to keep the team together," said He. "They were extraordinary graduate students."

Unlike the labs and companies that had tried before, He had a team that understood every component of the detectors, and they were all about to graduate. If he couldn't hire them, they would scatter to various companies.

Fortunately for He and his students, U-M had a solid infrastructure for faculty startups. In 2009, with strong support from Stephen Forrest, then the vice president for research, the University launched the Michigan Venture Center.

The Venture Center helps faculty inventors draw up business plans, assess the potential of their technologies, and connect with investors. It also helps faculty acquire "gap funding" to bridge the end of eligibility for academic grants and the beginning of interest from private


PHOTO: Joseph Xu

Farnam Jahanian, who co-founded Arbor Networks with Rob Malan, a research scientist in Jahanian's group at U-M.

Pathfinding

While U-M has great support for startup companies now, things were different in 2000 when Farnam Jahanian, then the Edward S. Davidson Collegiate Professor of Electrical Engineering and Computer Science, and Rob Malan (MSE CSE '96, PhD '00), a research scientist at the time, founded Arbor Networks.

Malan started out with Jahanian monitoring Internet traffic through the network node at Michigan—how much data was flowing, where it came from, and where it was headed.

"When you find things that don't make sense, a lot of times it turns out to be bad guys," said Malan.

Cyberattacks were just becoming a reality of the web in the late 1990s, so by 2000, there was a market for solutions that could shut them down. Jahanian and Malan discovered patterns in the traffic that indicated an attack. Then they developed software that could automatically detect these patterns and block the unfriendly traffic, allowing real users uninterrupted access to the website.

The inventors had help from the tech transfer office to secure patents and agree on how much of the company the University would own. But when it came to initial funding, they were on their own.

Jahanian and Malan already had research connections with HP, Cisco and Intel, and these colleagues introduced them to the venture capital arms of the companies. The computer giants offered money but no governance—they needed to find a lead venture capitalist to take them on.

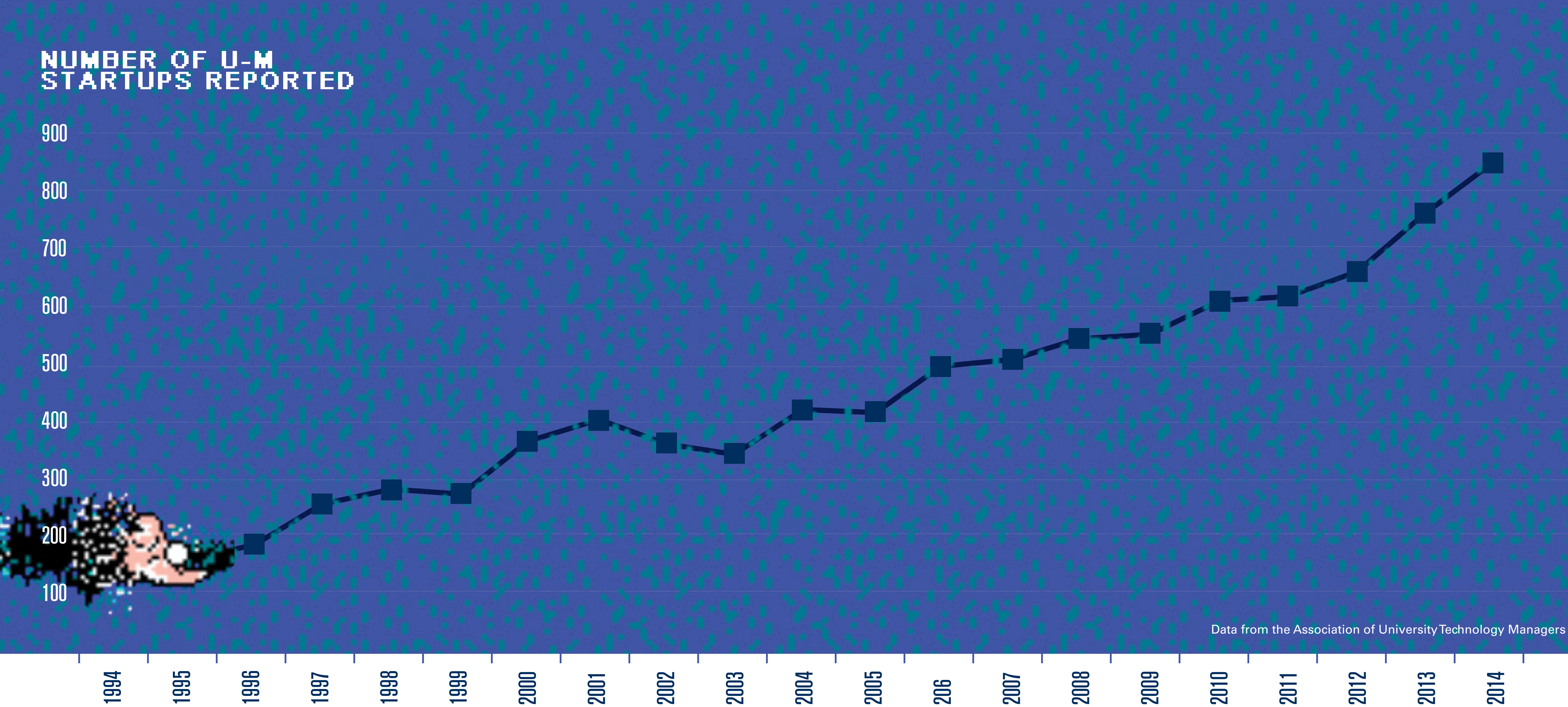
Lead venture capitalists serve on the startup's board, in addition to funding the company. Malan learned getting in touch with venture capital firms was as simple as picking up the phone. Ultimately, he and Jahanian found a match in Boston-based Battery Ventures.

The partner that he and Jahanian met, Todd Dagres, had experience building and running Internet infrastructure companies. "It's not that you want them to give money and get out of the way," said Malan. "VCs who have been executives are very valuable because they have scars and understanding that come only from experience."

With the backing and oversight of Battery Ventures, Arbor Networks was in business. The next hurdle was a round of hiring. Malan remembers walking into an interview for the vice president of sales, wondering "What does a vice president of sales do?" But he and Jahanian learned quickly with the help of the recruiter at Battery Ventures.

Looking back on the effort, Malan estimates that the foundational ideas only represented about 2 percent of the work needed to get Arbor Networks off the ground. "We had no idea what we were in for," he said.

"I never started out to be a businessman. I love doing research," he added. "But it's so fantastic to be able to listen to someone and solve their problem."



Data from the Association of University Technology Managers

"IN THE OLD DAYS, FACULTY MEMBERS DIDN'T WANT TO DO A STARTUP BECAUSE THEY WOULD BE LOOKED UPON AS SOMEONE WHO HAD GONE OVER TO THE DARK SIDE."

investors. Seasoned entrepreneurs serve yearlong rotations as "mentors-in-residence" to advise on all these steps.

"We didn't have any of that when we were getting started in the early 2000s," said Rob Malan, one of the founders of Arbor Networks (see "Pathfinding"). He has since served as a mentor for other U-M startup teams and is currently working on another new Ann Arbor business called Deepfield.

Through the Venture Center, He and his students learned about a business plan competition called Accelerate Michigan. They won the Defense and Homeland Security category, giving them $25,000 to get started. The College of Engineering also kicked in close to $20,000 for parts.

"The first prototype was built during evenings and weekends," said He.

H3D secured its first government contract to build a prototype and then four military-grade radiation cameras in 2012. These large cameras were roughly the size of a carry-on suitcase, and building them kept the company going through August of 2013. In January of that year, they won a bid for a $2.7 million contract with the Department of Defense (DoD) to build a smaller handheld version. Things seemed to be coming together.

FAILURE MODES

Every startup faces "mortal threats" said Forrest, the Peter A. Franken Distinguished University Professor of Engineering and the Paul G. Goebel Professor of Engineering in Electrical Engineering and Computer Science (see "Before their time"). He quoted Sherwin Seligsohn, mentor and angel investor to Forrest's third startup: "He said, in his New Jersey accent, 'Steve, you have to slay dragons.'"

Investors back out, new competing technology comes along, an important hire doesn't work out, or a difficult puzzle arises in the design or manufacturing. But some dragons are more fearsome than others. For H3D, the big one was that $2.7 million contract—when it fell through.

In the spring of 2013, the DoD performed audits: one technical, which they aced, and the other financial, which they flunked. Startups don't have much money in the bank. The DoD decided not to offer the contract in May. The team knew that they would be out of cash in September.

Many startups would have the option of venture capital at or before this point, but H3D was too niche. At the time, venture capitalists imagined a market for just 350 or so of these cameras—one for every nuclear power plant in the world, maybe, but no more.

To survive, H3D needed a commercial product fast. So He and his five most recent PhD graduates buckled down and made one. They worked long hours, and the founders went without pay for up to 3 months. If they couldn't afford to, He paid them from his own savings.

But the team was confident that the sacrifice was temporary—aware that H3D had no funding, the DoD was setting the company up with a contract that the military considered a safer investment. Still, that money wouldn't come in until September 2014—a year after H3D had finished its previous contract.

So He's team focused on the task at hand: launching a product. As early as December


PHOTO: Joseph Xu

Siuon Tung decants fluid containing the building blocks of the battery divider into a beaker.

Reinventing the invention

Sometimes, the initial idea for an invention and what the market wants from it are two different things. Around five years ago, Nicholas Kotov, the Joseph B. Florence V. Cejka Professor of Chemical Engineering, and student Siuon Tung wondered whether a divider made from recycled Kevlar could prevent fire-starting shorts in lithium-ion batteries. They ran an experiment, and the results were enough to justify a patent on the concept.

However, it wasn't the kind of patent that would license itself. So, when the Center for Entrepreneurship (CFE) invited Kotov to propose a case study to Master of Entrepreneurship students in the fall of 2013, he brought them the Kevlar battery divider.

As he presented the technology, Kotov noticed a tall young man with big hair watching intently. This fellow, John Hennessy, saw potential.

"The technology was advanced enough that we could take it somewhere, and there was a huge upside for batteries and electric vehicles if it could be realized," said Hennessy, now the CEO of the startup, Elegus Technologies.

With two other entrepreneurship students, Kotov, Tung and Hennessy developed the concept for the product—a divider between electrodes in lithium-ion batteries that would be much safer than the standard divider, without adding bulk. But in spite of the recent Boeing 787 fires, improving safety did not interest the battery industry.

To find out what industry did want, the Elegus team spent the fall of 2014 in the National Science Foundation's Innovation Corps (I-Corps) program, an entrepreneurship boot camp for faculty startups. I-Corps, started in 2011, is an effort to support research-inspired entrepreneurship at a national level. Companies that go through it are on the short list for federal grants aimed at tech startups.

"It's a grueling process," said Kotov. "During the program, the coaches and instructors kick your soft spots very intensely."

After 100 interviews with representatives of companies that might have an interest in the new dividers, the Elegus team understood that battery customers demanded more capacity—safety levels are considered adequate. And the new separator could meet this demand because it can be thinner than current dividers without sacrificing safety, leaving more room for electrode materials.

Elegus also needed to develop the idea to the point that industrial partners could see a path to using the new dividers into their existing manufacturing process.

"The current structure of large-scale industry, especially in the battery field, does not allow integration of new materials," said Kotov.

They did that work with help from the Michigan Translational Research & Commercialization program, run through the CFE and the U-M tech transfer office. After rounds of vetting that Kotov compares to the heavy scrutiny from I-Corps, Elegus received $175,000, funded in part by the State of Michigan.

Having solved many of the technological challenges posed by using a thinner divider in a battery, Elegus has now teamed up with XALT Energy, which Hennessy says is one of the largest lithium ion battery manufacturers in the U.S. Last summer, the two companies launched a joint venture in which Elegus will offer its patented ideas and XALT will provide funding to explore how to manufacture batteries with the new dividers.

"It's full speed ahead," said Kotov.

Arbor Networks moved to this large office in south Ann Arbor in 2008. It is now headquartered in Burlington, MA with offices in Ann Arbor, London and Singapore.

PHOTO: Arbor Networks

2012, H3D had a beta version of the hand-held Polaris-H radiation camera, which displayed its augmented-reality image of the radiation in the room on a Nexus tablet.

Weiyi Wang (MSE NERS '08, PhD '11) referred to the early prototypes as "Willy Kaye hack boxes," named for the company's president at the time. Kaye (MSE NERS '08, PhD '12), who took over from He as CEO in 2014, housed the crystal and electronics in off-the-shelf Pelican cases, modified by hand-drilling and mounting parts inside and out.

H3D received feedback from two early adopters through 2013. In December, they took a polished product in a sleek aluminum case on the road to nuclear power plants that had expressed interest. They had four orders by the end of the month. Then, they had to build the cameras. "We pretty much worked through the holiday," said Wang, now an engineer and the sales director at H3D.

Demanding hours are par for the course in the startup world, but He didn't take his team's dedication for granted. "It was amazing to me that the team was so determined," said He.

They were all personally invested in making the new technology succeed, and they also didn't want to let one another down. They kept H3D afloat until the next government contract came in. The next December, the team found themselves working through another holiday rush—but this time, H3D had money to spare for bonuses.

CASH FLOW

Access to information has helped smooth the startup process considerably, but one weak spot for many universities is access to investors. Startups are generally risky investments, and some research-inspired technologies, like He's, are so new that the market is difficult to assess.

But the numbers suggest that U-M startups are actually good bets. While the number of startups that live for four years or more hovers around 50 percent, U-M startups beat these odds with a survival rate above 80 percent, said Mark Maynard, marketing manager in the U-M tech transfer office.

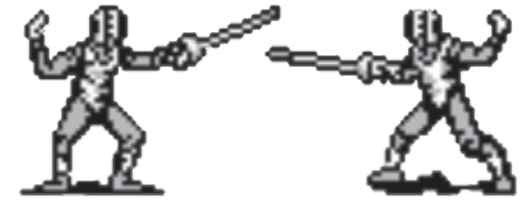
The venture capital firm Osage ran the numbers on 20 years of U-M faculty startups and found that if U-M had invested equally in all of them, the return would be "very attractive," according to a Marc Singer, a managing partner at Osage. So starting in 2011, U-M began to use its own endowment money to back faculty startups that already had investment commitments from venture capital firms.

This is a smart move, according to Walter Valdivia, a research fellow at the Brookings Institute in Washington, DC. His analysis showed that licensing patents doesn't pay the bills at most tech transfer offices—for 85 percent of universities, they are a net loss to the university's general fund. This is partly because two thirds of the income typically goes straight to the inventors and the associated lab or department.

But startups could change the game if universities invest in them. The value of an invention grows rapidly as a startup hammers out solutions to its potential problems, and U-M is not the only university that can benefit by backing its own technologies early. University startups are a national trend—the number of new startups reported to AUTM has more than quadrupled since 1994. In that year, U-M had zero. Last year, it had 19.

States play roles in helping research-inspired businesses get off the ground as well. Gap funding for U-M startups often comes from the state through bodies such as the Michigan Economic Development Corporation (MEDC). One recent recipient of funding from the MEDC is the battery startup Elegus Technologies (see "Reinventing the invention"). And Michigan isn't alone: many other state governments are investing in small businesses, particularly in the Midwest.

All told, the developments are beginning to create the economic impact that the signers of the Bayh-Dole Act hoped for. Over the last 16 years, the technology transfer office at U-M boasts more than 2,000 jobs created, many of them in the state. And as of the end of 2014, over 4,400 businesses existed because they spun out of universities nationwide, including 137 from U-M.



"EVERY DAY WITH A SMALL COMPANY, THERE IS A THREAT. AND THAT THREAT IS A MORTAL THREAT."

FROM STARTUP TO FINISHER

Funding challenges aside, the success of a startup comes down to one question: Is this a product that someone wants?

Fortunately for H3D, the prospective investors were wrong about the potential market for a room-temperature radiation camera. Some nuclear power plants now have four of the new handheld cameras, which are significantly cheaper and easier to use than the old industry standard: 40-pound cryogenic radiation detectors. H3D is preparing to launch a new commercial camera based on the cancelled grant, a handheld design with better identification of radiation sources.

With greater support for faculty startups at universities across the U.S., more research-inspired technologies will make it into the hands of potential customers. And if U-M's experience is anything to go by, the universities will measure their impact not just in degrees and research articles but also in new local jobs.

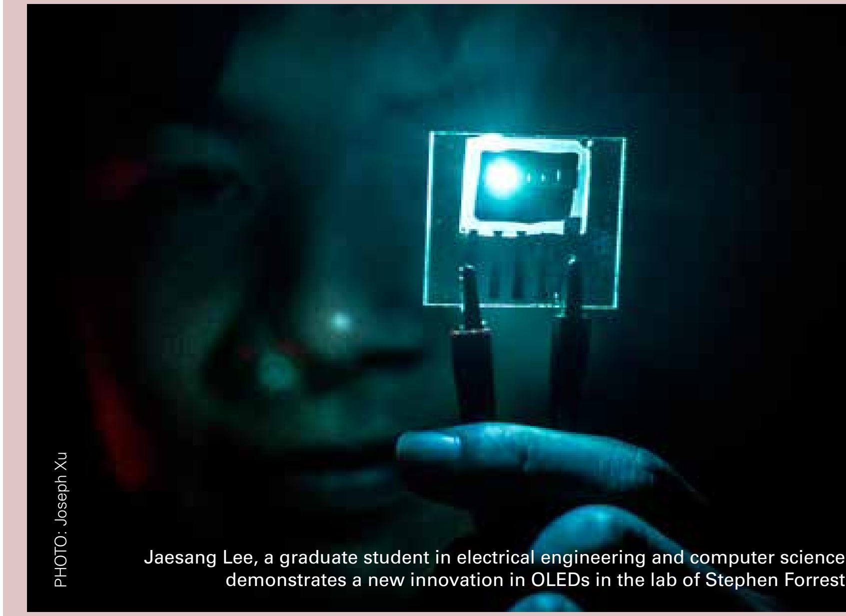


PHOTO: Joseph Xu

Jaesang Lee, a graduate student in electrical engineering and computer science, demonstrates a new innovation in OLEDs in the lab of Stephen Forrest.

Before their time

When Stephen Forrest partnered with Mark Thompson while working at Princeton in 1993, their work rapidly advanced the nascent technology of organic light emitting diodes, or OLEDs. Thompson was already in contact with investor Sherwin Seligsohn, who immediately took a shine to their OLED work.

"It's a new kind of light!" Forrest remembers Seligsohn saying.

It was very early days for OLEDs—they had efficiency problems, reliability problems, and they couldn't yet cover the whole range of colors needed for a high quality display. But if they could work, it would be possible to make a display that didn't need a backlight. The screen would have better contrast and require less power. It wouldn't even have to be flat.

Seligsohn was a believer, and Forrest and Thompson were confident that they could overcome the challenges by tinkering with the chemical makeup of the light-emitters. They founded Universal Display Corporation in 1994 to continue working out the kinks as the problems advanced beyond academic research and entered product development.

Seligsohn mentored Forrest and Thompson and warned them about the road ahead, delivering his line about slaying dragons.

"And what he meant by that was every day with a small company, there is a threat. And that threat is a mortal threat," said Forrest. "You need to know how to deal with it to get on to the next mortal threat."

They needed a CEO, more investors and staff. They had to watch out for other technologies that might take over their market. And they had to perfect the efficiency, color, brightness and reliability of their OLEDs. But the biggest problem they had was that it was too soon for the technology.

"I went to Japan because that was the only place that was even thinking about making displays out of OLEDs," said Forrest. "I think I went to Japan 50 times."

Nothing ever came of it. Still, the team stayed optimistic and kept meeting with potential customers.

Finally, in the early 2000s, Samsung in Korea licensed Universal Display Corporation's technology for what would become its flagship smartphone. The Galaxy S, released in 2010, sported the first commercial display underpinned by Forrest and Thompson's discoveries.

Profits didn't come in until 2012. But after that, the success was astronomical. Samsung and LG branched out to fully OLED TVs, some curved to take advantage of the display's flexibility. Universal Display Corporation has reported more than $100 million in profits each year for the past three years.

OUT OF THE #FLOOD

In the face of disaster, a city's social media is saving lives and infrastructure. Is this just the beginning for crowd-sourced salvation?

STORY BY: Ben Logan
PHOTOS BY: Marcin Szczepanski

BPBD DKI Jakarta
@BPBDJakarta
#Banjir on RT. 02, 04, 05/Rw. 09, South Kembangan, Jkt Bar, an average of 50 cm, is currently continuing to recede @B
7 5

kiki riski maulina
@kirismaul
@petajkt #banjir in kampung rambutan kecamatan Jakarta is as high as the thigh of an adult
4 1

PetaJakarta.org
@petajkt
Update to the latest #banjir high in some areas of Jakarta this evening by @BPBDJakarta in PetaJakarta.org.
5 6

Frank Sedlar speaks with Ibu Atun on the doorstep of her flood-prone home.

The narrow, cracked pavement that weaves into the densely tangled neighborhood along Jakarta's Ciliwung River is still slick from the overnight monsoon storms. This vibrant cluster of life is called a *kampung* in Indonesian; the literal translation is "community" or "village." But in Jakarta, the word is used to describe a slum neighborhood. On Google Maps, this one appears as just a blank gray swatch. After a twisting series of blind turns, the riverbank comes into view. The overnight deluge has raised the water enough to drown fifteen feet of shoreline. Flotillas of newly immersed trash churn in the intensified current.

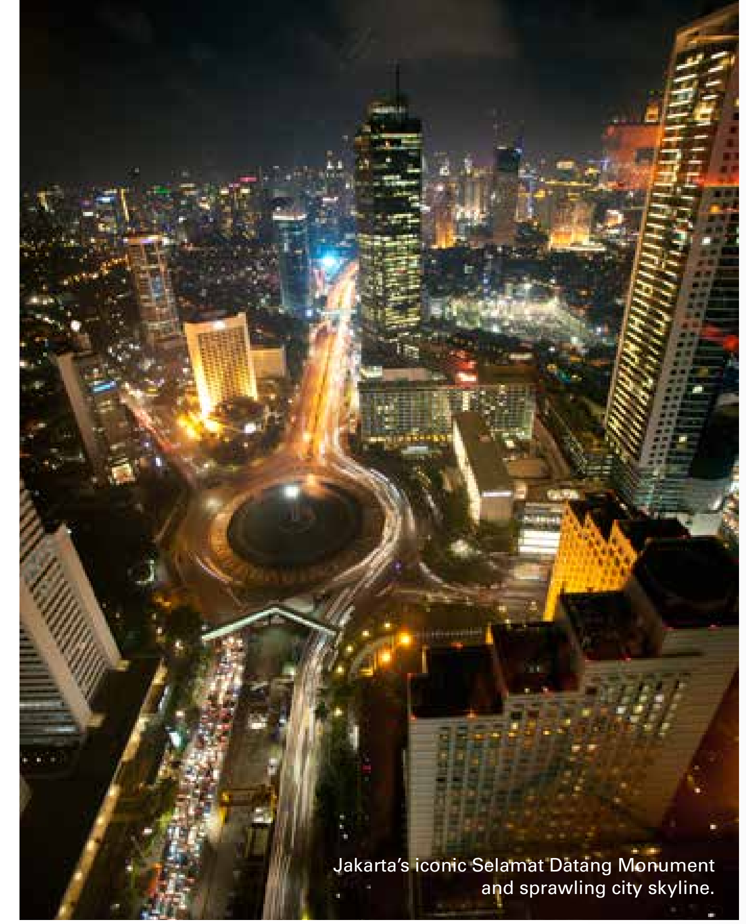
For 52-year-old Ibu Atun, the water is literally at her doorstep. She's lived in this community her whole life. Twice a month the water enters her house. When it's really bad, her family takes refuge in the nearby school. Atun describes how the frequency of bad floods has increased over the past five years. In 2014, her house was completely submerged. She relies on flood warnings from the neighborhood leader – who receives a phone call from a floodgate operator upstream.

Home to more than 28 million residents, Jakarta and its surrounding metropolis is the second largest settlement on earth. Nearly three quarters of the city is prone to devastating seasonal flooding. Although they've been fighting the water for hundreds of years, unprecedented urbanization and climate change have brought the situation to a tipping point. And where traditional solutions are failing, an innovative use of technology is making a difference.

Around the corner, two younger residents are immersed in their smartphones, swiping through their social feeds. They admit to being on them all the time – and can't imagine life without them. They explain how news of flooding often finds them through their phone.

These two encounters illustrate different ways in which people hear about (and share) news of flooding in Jakarta. Whether it be an announcement reverberating from the mosque loudspeaker, a phone call, the head of the neighborhood, their eyes or with social media – people don't rely on just one single piece of information about flooding.

Jakarta has one of the highest concentrations of mobile devices and social media activity in the world. By combining these two things with the GPS features inherent to both, the city is tapping into a crowdsourced way of tackling its flooding problem that was not previously possible. They are leveraging something known as geosocial intelligence to make real-time flood maps fed by the social media of residents on the ground – which provides lifesaving information to individuals and emergency responders alike. It doesn't involve costly, heroic construction projects or installing a vast array of new and expensive sensors along the exhausted canals and floodgates. Instead, open-source software elegantly taps into the on-the-ground knowledge residents have about flooding and turns it into a simple, up-to-date flood report. The emerging resource that geosocial intelligence offers is being realized in one of the most complex urban environments on earth. And what started as one small project is now proving itself as a model that can be used in global cities like Shanghai, Dhaka, Mumbai, Bangkok or even New York.



Jakarta's iconic Selamat Datang Monument and sprawling city skyline.

DESPERATION BREEDS INNOVATION

There is a long history of humans working together to make sense of their environment, especially when it does scary things, like erupt and shake. The way people began to understand and study earthquakes was primitive at first. "We didn't always know what those were," explains Etienne Turpin, cofounder of PetaJakarta.org. "We didn't know why they occurred and we didn't have any sensitive machinery to tell us where they were occurring. The sensors for earthquakes were human beings' bodies and their capacity to write down and share their experience of what happened." Those reports were the beginnings of a system which led to a theory of an earthquake.

Fast forward to today and the emergence of geosocial intelligence, a broad term based on the data that GPS-enabled smartphones can now provide. Like with most innovations, advancements have come in waves. Coincidentally, it was an earthquake that led to an important breakthrough. The 2010 Haitian earthquake death toll was estimated around 200,000. "During an emergency situation the number one resource is information," agree Turpin and Tomas Holderness, PetaJakarta.org co-founders. "There was no formal data about where the hospitals, schools or roads were," explains Holderness. That's when volunteers and local residents offered crowdsourced help. Using the open-source mapping platform Open Street Map, individuals mapped small sections. This quickly produced a large map that was used by the Marine Corps as an important mode of intelligence for rescue and recovery. That sparked a major shift.

"It went from, 'Cool, we can collect geographic information about different places in the world and make it freely available,' to, 'We can use that information to actually have a really big change,'" says Holderness. Local knowledge fills the Open Street Map that displays PetaJakarta's flood data. Ibu Atun's neighborhood, which appeared as a gray swatch on Google, has street-by-street detail on Open Street Maps.

Although PetaJakarta.org is based at the SMART Infrastructure Facility at the University of Wollongong in Australia, the team's roster includes a number of key players with Michigan connections.

ETIENNE TURPIN, PH.D.

Cofounder of PetaJakarta.org. In 2011 he began a 19-month journey at the University of Michigan A. Alfred Taubman College of Architecture and Urban Planning and the Center for Southeast Asian Studies. There he was a lecturer, research fellow and helped lead a project that brought U-M students to Southeast Asia to look at climate change and urbanization. One of those students was a Civil and Environmental engineering undergrad named Frank Sedlar. Currently, Turpin lives in Jakarta as a research fellow with the SMART Infrastructure Facility.

FRANK SEDLAR (BSE CEE '13, MSE '15)

Visiting Fulbright researcher at PetaJakarta.org. As the only civil engineer on the team, he focuses on analyzing the Jakarta government's efforts to address the flooding problem with traditional construction, like canals and seawalls. His hope is that data collected by PetaJakarta.org will inform future construction projects so that they disrupt or displace as few lives as possible.

MATTHEW BERRYMAN, PH.D.

IT architect for PetaJakarta.org at the SMART Infrastructure Facility. His expertise includes modelling and analysis of large systems. During his Ph.D he spent two summers at U-M's Center for the Study of Complex Systems under the supervision of Dr. Cosma Shalizi.

North Jakarta's seawall near the Waduk Pluit reservoir.


Sedlar atop North Jakarta's precarious seawall.

The most recent wave of innovation has just recently crested. With ubiquitous satellite connectivity, and the mass adoption of GPS-enabled smartphones and social media, user-generated info-maps have become quite common for identifying everything from sanitation issues to crime and disease outbreaks. One of the most popular examples is the Waze app. Its millions of users open the app while driving and contribute to traffic reports, mark speed traps and offer shortcut suggestions. Another example came in the aftermath of the Fukushima nuclear disaster. The Japanese federal government was providing broad-stroke radiation averages that may have been of limited value – a single reading for an entire city, for example. A nonprofit called SAFECAST developed Geiger counters that could be attached to bicycles, cars or backpacks to measure localized radiation levels every five seconds. Users then uploaded that data to a free mobile app, which populated a public map.

What's happening in Jakarta has an important distinction. The PetaJakarta.org system doesn't require people to change their behavior or do anything special, like download a new app. There's no new hardware or reporting portal. During floods, PetaJakarta.org simply tracks the information and photos that residents are already posting on their social networks. It then confirms and broadcasts those conversations onto a simple online map that visualizes flood levels across the city.

"I think this an incredibly important trajectory, especially given the constant complaint about how social media is alienating and a waste of time," exclaims Turpin. "Well, there may be some truth to that, but our job as researchers is not to critique those systems, it's to put them to work toward some better end."

A SINKING CITY

Traditionally, cities tackle flooding problems with civil engineering, by building walls, flood gates and canals, or in extreme cases, redirecting the flow of rivers. Jakarta is no different, but traditional approaches aren't doing enough – and in some ways makes things worse.

Before the evening downpour, the mid-morning sun intensifies the tropical humidity. Frank Sedlar is perched on top of an all but abandoned, 100-year-old floodgate. Over his shoulder is a kampung that overhangs the banks of the Ciliwung. "You build flood resiliency through community, not concrete," says Sedlar, U-M Civil Engineering alumnus and PetaJakarta.org visiting researcher. "We need to engage with these communities because they are the real flooding experts on the river. They know more about water conditions than any engineer in the city." However, in many cases, these communities are being evicted to make way for construction. The homes, family businesses and favorite swimming spots will be replaced with cement canal walls. These canals are part of an elaborate system that has massive energy requirements. Yet it's incredibly fragile. If one floodgate or pump house fails, it's a domino effect downstream. A single break in the chain can cause flooding to inundate major thoroughfares, causing city life to grind to a halt. Water levels can rise in a flash, threatening riverside communities. These abrupt, compounding effects mean real-time information is invaluable to residents and emergency responders.

A 30-minute rickshaw ride north through Jakarta's never-ending traffic leads to a cornerstone of the city's flood fighting system, the Waduk Pluit reservoir. It's where the water from the city's central canal system is pumped over a precarious seawall into the ocean. Sedlar walks along the wall, which is roughly a foot thick and peaks only a few inches above the waterline.

> "These communities … know more about water conditions than any engineer in the city."
>
> **FRANK SEDLAR (BSE CEE '13, MSE '15)**

Small leaks trickle out of cracks into the narrow road that lines the dubious barrier. "This is all that is protecting Jakarta from the sea," says Sedlar. "If this were to break, about 40 percent of Jakarta would be flooded to a depth of one to two meters." It's a frightening scenario for the poor communities that literally live on and around the wall. In the distance, dark sludge is pumped from the reservoir into a barge which will be dumped offshore at the site of the new seawall project. With a price tag of nearly $40 billion, the decades-long endeavor is the biggest civil engineering project on earth. In the end, the seawall will be 40 kilometers long, more than 24 meters tall and will have displaced thousands of people. If completed, it's difficult to know how long the lifespan of the wall will be. With no official plans released, some estimates suggest it may last only 65 to 100 years. Scan this page with the Decoder in the One Cool Thing app to watch a video that follows Frank Sedlar as he explores the reality of flooding in Jakarta and how PetaJakarta.org impacts the lives of residents.

Simultaneously, inland mega-construction sends increased runoff into the city's swollen waterways, while contributing to a startling rate of land subsidence – parts of the city are literally sinking between 5 to 20 cm each year.

BRIDGING THE GAP

While PetaJakarta.org doesn't solve the fact the city will flood during the monsoon, it does address the secondary fundamental problem of information. As the Haitian earthquake so gruesomely illustrated, information is critical in an emergency situation. Jakarta has roughly 680 miles of canals and 13 big rivers that drain to the ocean. According to Sedlar, there are only 26 sensors that measure the water levels. At any given time, about half of them are either broken, stolen or offline. There's very little real-time information on the water levels, which is critical for making decisions when operating floodgates and pumps – not to mention warning the public.

In the absence of traditional data, the team turned to crowdsourcing. "We told the city's emergency response department that we just installed 28 million sensors in the metropolitan area," says Turpin. "They asked, 'Well how did you do that?' 'Well,' we said, 'we just let people turn on their phone.'" Holderness and Turpin drafted one of six proposals that won a first-of-its-kind Twitter Data grant – more than 1,300 global applications contended for the opportunity. The grant gave the team special privileges and behind-the-scenes access to Twitter's geolocated data. If someone tweets with the hashtag #banjir (#flood), the system sees that and sends an automated request for confirmation. During floods, the system has handled 3,000 user requests within an hour, and 240 incoming tweets per second. Other residents see those tweets in real time and like or share them, which then encourages others to report. The way social media rewards users for engaging helps PetaJakarta.org gain popularity, creating a snowball effect.

Inside Jakarta City Hall, large digital dashboards overlay social media data on smart maps used by emergency responders to monitor and respond to flood situations.

> "People want to report information because they might need assistance, but also because they want to help their neighbors."
> **Chris Chiesa (BSE ME '85, MS '87)**

After a successful trial period, PetaJakarta.org began integrating other social platforms into its system. "It was relatively painless to add new data sources thanks to the modular architecture we used," says Matthew Berryman, the team's IT architect at the University of Wollongong's SMART Infrastructure Facility. "And the more data we've got on the map, the more useful it is." And because multiple platforms are feeding the map, if one goes down then another picks up the slack. In a disaster, it's good not to have all your eggs in one basket.

The sensory contrast between the flood-prone streets and the computerized control center at Jakarta's Disaster Management Agency at city hall is impressive. Honking motorbikes and vocal vendors are replaced with a quiet concerto of ticking keystrokes and clicking computer mice. Aging infrastructure and oppressive humidity give way to modern offices and air conditioning. BPBD DKI Jakarta is the governmental unit that collects incoming flood data and coordinates prioritized disaster relief. A three-by-seven meter digital dashboard illuminates its mission control room where flood data influences emergency response. Integrated into this dashboard is the PetaJakarta.org map. "Now we've got a map that's connecting the government's formal information system and the informal information from social media all into one space," says Holderness. "It's the connection of all those pieces in one pipe that gives the most valuable information about flooding at that current time. From what we've seen, I don't think that's ever really happened before."

During a flood, Bambang Surya Purta, informatics and controlling division head, runs the show. "We need more sensors throughout Jakarta," says Bambang. "PetaJakarta.org gives us millions of sensors that we don't have to maintain. It's a very useful tool for us." It's this tool that helps emergency responders spread information to floodgate operators, who then contact neighborhood leaders – like the one who tells 52-year-old Ibu Atun when to take refuge in the school. So although people who have mobile devices can access and contribute to the PetaJakarta.org map directly, it is helping others as well. Whether it reverberates over a mosque loudspeaker, from a phone call, a neighbor or social networks, information from PetaJakarta.org permeates public awareness.

GEOSOCIAL FUTURE

The geosocial intelligence being leveraged in Jakarta is part of a growing trend toward smarter cities. However, at this point, that future typically involves integrating costly, energy-dependent digital sensors into the fabric of our homes and communities, a concept often referred to as the Internet of Things.

"There is no such thing as a smart sensor – a sensor is dumb, it does one thing," says Turpin. "It reads a temperature, water height or whatever. A human being can look around, smell, hear and use a whole variety of their sensory and mediated relationships to relay information in an emergency."

Holderness agrees. "A sensor cannot convey the criticality of a flood wall collapsing. It can merely tell you that there has been a change in the electrical signal that it measures."

Although the team sees potential in the Internet of Things for disaster management, they suggest a different trajectory. They believe that rather than teaching computers to learn what human being are doing, perhaps we should put more effort into using computers to work *with* people – to learn how to help each other. Instead of addressing challenges with more digital sensors, algorithms and code – some problems require less code, less technical dependence. Instead of building something completely new, why not use what already exists – in innovative ways.

Instead of what Turpin describes as location-based irritation – like what happens when you get a doughnut advertisement on your phone when you walk by a Krispy Kreme – he asks, "What about location based mutual aid? How we can build tools for communities that help them share and allocate resources in ways that we haven't come close to in our several thousand years of experimenting with democracy?" For the researchers, the real challenge is finding ways to take crowdsourced science from where it is now to a scale where it helps cities become better designers of their own future.

Smiling, Turpin imagines returning to Jakarta in 10 years and finding their map running autonomously by its users and the government. "That is also the fantasy that I won't be living in Jakarta in 10 years," he laughs jokingly about his adopted, flood-prone city. For the team, an even greater aspiration is modestly described by Holderness. "We've built on other people's open-source software and we hope other people will build on ours and use it elsewhere."

In the meantime, the success of PetaJakarta.org is gaining momentum and may expand to other cities in Indonesia. Alumnus Chris Chiesa (BSE ME '85, MS '87), deputy executive director of the Pacific Disaster Center, recently visited with PetaJakarta.org personnel. "We have a proposal in for a PetaSurabaya," he said, illuminated by the glow of Jakarta city hall's massive digital dashboard. His visit is part of a growing interest by the broader disaster agencies at the national level to integrate local knowledge, like what PetaJakarta.org provides, into their own systems.

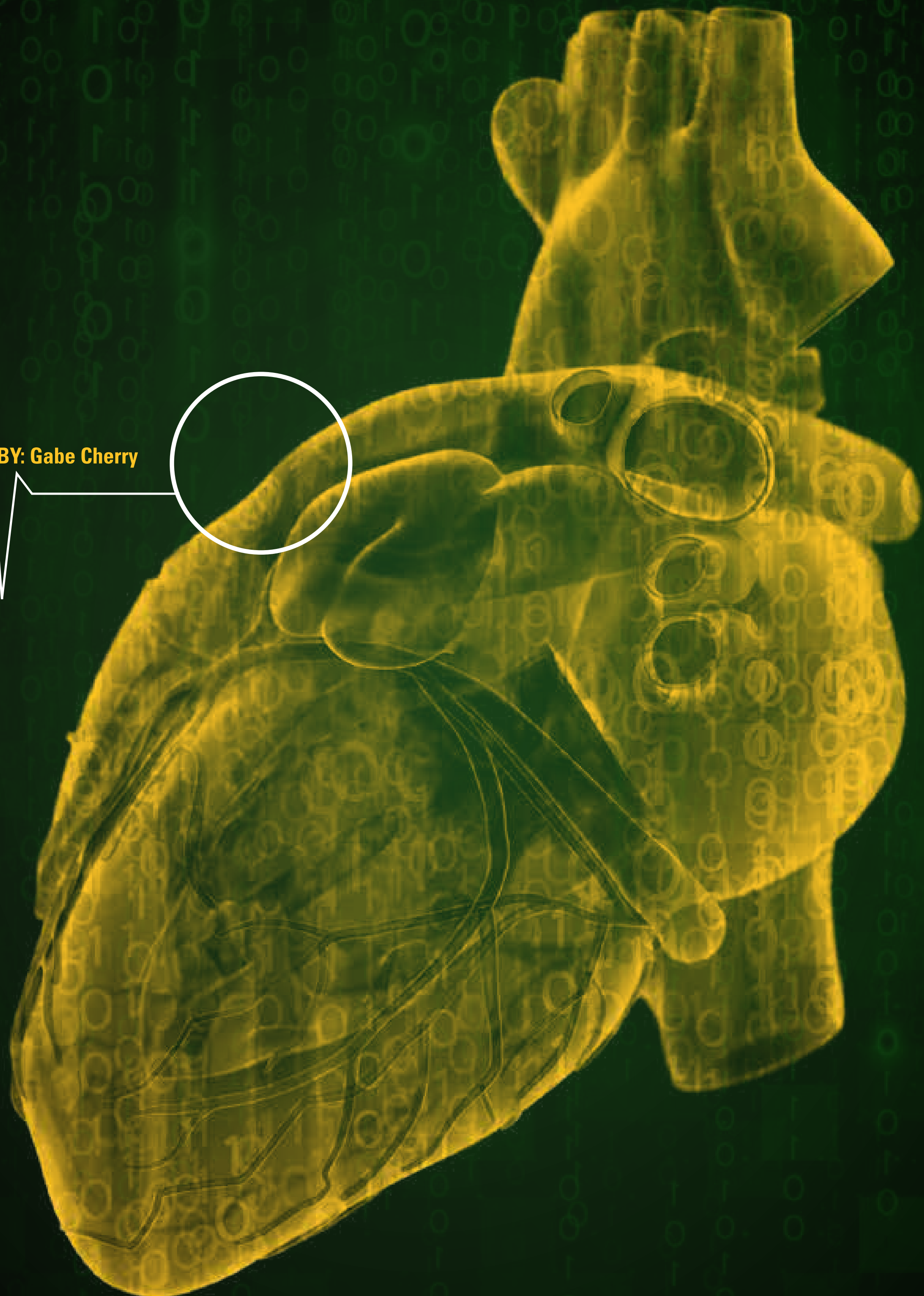
Chiesa and Sedlar exchange "Go Blue's" after a discussion about the importance of maintaining a local identity within tools like these. "People want to report information because they might need assistance, but also because they want to help their neighbors," says Chiesa. "If you dilute that too much on a national level, you might lose some of that significance." The collaboration is now poised to spread "Petas" across the country. And as extreme weather and sea levels continue to increase, it might not be long before we see a PetaMumbai, or even a PetaNewYork.

As for Ibu Atun and the millions of other families like hers, the next devastating flood is just a matter of time. But when it does come, there will be a faster, more intelligent response.

INSECT MEDIA

One of the concepts that has become interesting to the researchers in trying to understand geosocial intelligence is stigmergy. Stigmergy is the way in which insects like ants and other swarm-capable creatures mark their environments to coordinate action. Typically, they use pheromones as datapoints that are traceable to their bodies. It allows them to interact dynamically with one another in an environment. For example, when an ant senses some sugar spilled on the counter, it can mark that so others can come collect. When the colony is at risk, signals go out to protect the queen. Now imagine if humans could do something similar. While walking down a city street, if someone witnesses suspicious activity happening in a dark alley, their autonomic bodily response could trigger a warning signal. That signal could be picked up by others on that street to avoid the alley. Perhaps if enough similar signals come from that block, the authorities would be alerted. Or maybe the city would decide to install a street light, or increase patrol.

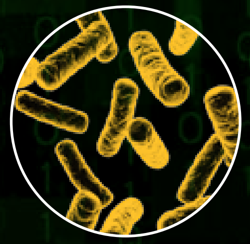
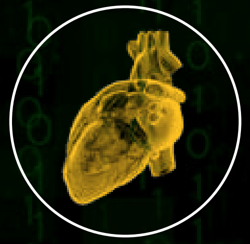
As we move toward more wearable and even implantable technology, might there be a way for us to capitalize on this kind of insect media? "I think we can," says Turpin. In his opinion, the real challenge is not the automation of this kind of system. Instead it's figuring out ways to use it to help solve more common problems – things that aren't as large-scale as a flood or earthquake, but still require a lot of attention and support.



STORY BY: Gabe Cherry

HACKING HEALTHCARE

HOW BIG DATA IS DRIVING BIG CHANGES IN MEDICINE

Jenna Wiens isn't a medical doctor. But someday, her work might save your life. It won't be because she developed a new medicine or invented a revolutionary surgical procedure. Instead, you might owe your extra years to one of her algorithms.

Wiens, an assistant professor of computer science and engineering at U-M, is one of an army of data scientists and other engineers who are descending on healthcare to tackle what could be the most massive data science puzzle the world has ever seen: a movement to transform medicine by harnessing information about patients much more effectively. The effort, known broadly as precision medicine, is expected to help doctors customize treatments to individual patients' genetic makeup, lifestyle and risk factors, and predict outcomes with significantly higher accuracy.

One major branch of precision medicine is the development of big-data tools to customize treatments. Experts envision a future in which doctors and hospitals can draw on a web of constantly churning analytical tools that mash up data from a huge variety of sources in real time – for instance, your electronic health record, genomic profile, vital signs and other up-to-the-moment information collected during a hospital stay or via a wearable monitor. It could give doctors and hospitals the ability to make meticulously informed decisions based on an analysis of your entire medical history, from birth to right now.

Researchers like Julia Adler-Milstein, an assistant professor at the U-M School of Information and School of Public Health, say that in some ways, today's move to data-driven medicine is similar to the move to data-driven retailing that took hold over a decade ago. Online sellers like Amazon have compiled exhaustive data stockpiles, analyzing years of browsing and purchase history for millions of customers, then using that past data to predict what you'll buy next. It's obsessively detailed, computationally advanced, and sometimes a little creepy – and it has revolutionized how consumer goods are sold. If a computer can analyze your purchase data to predict what you'll buy next, why can't it analyze your medical data to predict whether you'll get sick? It's an enticing question for doctors and data scientists alike. But, as with most things in healthcare, it's complicated.

"Amazon's decisions are tightly intertwined with data. But healthcare has only started to evolve the model of decisions based on physician expertise," Adler-Milstein explains. "That has always been exciting to me, and learning how to integrate data and information technology pieces into the complexity of healthcare is especially fascinating."

Perhaps it's no surprise that bringing healthcare data into the 21st century is tougher – far tougher – than building an algorithm that suggests new socks to go with your new shoes. The stakes are higher. The regulations are tighter. The costs are greater. And there's more data. So much more data.

Eric Michielssen, the Louise Ganiard Johnson Professor of Engineering at U-M, predicts that the amount of healthcare data generated annually worldwide will rise to 2,300 exabytes (2.3 trillion gigabytes) by 2020. And new data sources are coming online all the time, from wearable sensors to new kinds of imaging and video data. It's predicted that healthcare data will eventually push past traditional scientific data hogs like astronomy and particle physics. Much of this is due to genomics data, which gobbles up so much space that there isn't a cloud big enough to hold it – scientists are largely limited to on-site data storage. One researcher even joked that "genomical" might soon overtake "astronomical" as a term for incredibly large things. And much of this data is piling up across a fragmented hodgepodge of systems that were never meant to work together, at hospitals and other healthcare players that are often reluctant to share it.

Syncing up an ocean of fragmented, inconsistent data with the advanced analytics and databases that will drive precision medicine knowledge seems like an impossible problem. But maybe that's what makes it so attractive to engineers. Today, more of them are working in healthcare than ever before, at U-M and elsewhere. Biomedical experts, data scientists, electrical and computer science engineers are dedicating their careers to it, and healthcare providers, tech companies and the government are investing massive amounts of resources. With the challenge ahead of them, they'll need it.

FIGHTING INFECTION WITH DATA

Wiens, for her part, is working on front line tools – the system of analytics and other digital machinery that will turn raw data into knowledge that doctors can use to make better decisions. Among her projects is a tool that predicts which hospital patients are at risk of developing a life-threatening intestinal infection called *Clostridium difficile*, or *C. diff.* The disease has evolved into an antibiotic-resistant superbug at hospitals, where it affects an estimated 500,000 patients per year in the United States alone.

"HEALTH DATA IS GOING TO BE VALUABLE IN WAYS WE DON'T EVEN UNDERSTAND YET."

JENNA WIENS
ASSISTANT PROFESSOR OF COMPUTER SCIENCE AND ENGINEERING, U-M

The actions that can slow the spread of *C. diff* can be surprisingly simple, like moving high-risk patients to private rooms or limiting their movement around the hospital. The trouble is, doctors don't have a good way of figuring out who's at risk.

Wiens' team is solving the problem with machine learning, a technology that's already widely used in online marketing and retailing and is gaining ground in precision medicine. It enables computers to "learn" by combing through vast pools of data, using elaborate mathematical algorithms to compare pieces of information and look for obscure connections. They then use those connections from past data to make predictions about the future.

Data is the raw material that makes tools like this possible. And the team gained access to a lot of it at the project's outset: the entire electronic health record for nearly 50,000 hospital admissions at a large urban hospital. The data also included demographic information and detailed records of each hospital stay: vital signs, medications, lab test results, even their location in the hospital and how prevalent *C. diff* was in the hospital during their stay.

Armed with this cache of data, they set out to build a tool that could estimate a patient's risk of developing *C. diff* by going far beyond known risk factors and analyzing thousands of variables in a way that humans can't. It would look for relationships between variables, calculate how

FIGHTING DISEASE WITH DATA

More and more researchers are finding ways to use data to keep people healthy. Here are a few examples of the latest data-driven health projects at U-M.

MANAGING BIPOLAR DISORDER

A proposed smartphone app could listen to the voices of bipolar disorder patients, analyzing subtle changes in voice and speech to predict episodes before they happen. Emily Mower Provost, an assistant professor of electrical engineering and computer science, Satinder Singh Baveja, a professor of electrical engineering and computer science and Melvin McInnis, the Thomas B. and Nancy Upjohn Woodworth Professor of Bipolar Disorder and Depression at University of Michigan Medical School.

OUTSMARTING THE FLU

A DARPA-funded research project is using big data to determine why some people who are exposed to germs like the flu get sick while others stay healthy. It could help doctors better understand the immune system and protect patients from disease. Al Hero, the John H. Holland Distinguished University Professor of Electrical Engineering and Computer Science.

PUTTING HEART PATIENTS IN THE RIGHT PLACE

A big-data analytics tool can predict which patients are at high risk of complications from cardiac stent surgery, enabling doctors to route high-risk patients to hospitals with the facilities to handle an emergency. Zeeshan Syed, an assistant professor of electrical engineering and computer science.

MAKING ABDOMINAL SURGERY SAFER

A predictive model can analyze abdominal core muscle size to predict which patients are at high risk of complications from abdominal surgery. The tool could help physicians pinpoint risks and take preventative measures to keep patients safe. Stewart Wang, an endowed professor of burn surgery and a professor of surgery at University of Michigan Medical School.

PREVENTING HOSPITAL INFECTIONS

A predictive tool can spot patients that are at high risk for a potentially deadly intestinal infection called *Colostridium difficile* (or *C. diff*), enabling doctors to take measures that can keep them safe. Jenna Wiens, an assistant professor of computer science and engineering.

turn it all into a numerical score that estimates an individual patient's probability of becoming infected with *C. diff* during their hospital stay.

It was a tall order, particularly because of the complex way the risk factors change during the course of a hospital stay. So the team used what are called multi-task learning techniques. Multi-task learning breaks a single task into several individual problems, looks for common threads and connections between each problem, then combines them into a single model.

The research team comprises dozens of experts on infectious disease and machine learning; its founding members include John Guttag, a professor in the MIT Department of Electrical Engineering and Computer Science and Eric Horovitz, Technical Fellow and Director at Microsoft. They started by crunching the patient data into binary variables that a computer can understand, ending up with around 10,000 binary variables per patient, per day. They then broke the task into six individual machine learning problems (see equation).

Finally, they set the computer to work trawling through the data to build (or "learn") a model. When the dust cleared, their learning algorithm found connections between *C. diff* and everything from patients' specific medication histories to their locations in the hospital. It was a model that no human could have come up with, and a far cry from the quick bedside analysis that doctors rely on today.

Testing showed that their model was more effective at predicting which patients would get *C. diff* than current methods, correctly classifying over 3,000 more patients per year in a single hospital. Perhaps most importantly, it predicted who was at risk nearly a week earlier, providing more time to identify high-risk patients and take potentially life-saving action.

Wiens says the computing power needed to run the model at a hospital is minimal. It's already being integrated into one major hospital's operations and could be rolled out at others in as little as a year, crunching actual patient data in real time to identify high-risk patients and alert doctors.

> "SOMETIMES SCIENTISTS AND DOCTORS DON'T KNOW WHAT TO LOOK FOR, AND I THINK THAT'S THIS MILLENNIUM'S CHALLENGE."
>
> BARZAN MOZAFARI
>
> ASSISTANT PROFESSOR OF COMPUTER SCIENCE AND ENGINEERING AT U-M

Wiens' model is just one of many data-driven analytical tools that doctors may one day use to make better decisions and tailor treatments and medications to individual patients. Similar tools could predict which patients will suffer complications from heart surgery, more precisely target medications based on genomic and lifestyle data, and even predict the progression of complex diseases like Alzheimer's and cancer.

"Health data is going to be valuable in ways that we don't even understand yet," Wiens said. "It's going to move us away from a one-size-fits-all healthcare system and toward a model where physicians make decisions based on data collected from you and millions of others like you."

But getting there isn't just a matter of doing the math. It'll take a new level of collaboration between data scientists, hospitals and others in the healthcare community. And in the world's most fragmented healthcare system, that could be even tougher than it sounds.

GOOD DATA IS HARD TO FIND

To build the kind of health system Wiens and others envision, we'll first need a better health data system. And that's an area where the go-go world of computer science collides messily with the more cautious culture of medicine. Hospitals are collecting more data than ever, but most of it is sitting idle on proprietary record systems that weren't designed to talk to each other. And for healthcare providers, sharing comes with risks: they worry about giving away secrets to competitors, angering patients, running afoul of vague privacy regulations and a variety of other pitfalls.

But that data is the lifeblood of the work that researchers like Wiens are doing. There are some large storehouses of data, and in fact U-M has one of the largest stores of genomic data in the world. But there's no central source of broad, widely accessible data. And that limits what researchers can do.

Wiens believes that the pace of discovery could increase dramatically if more data were publicly available. It would enable multiple researchers to use the same set of data, leading to more consistent research results and making it easier for researchers to verify each other's findings. It would also mean that research topics would less often be limited by the types of data available.

"My work is about taking data and turning it into knowledge, and sharing data publicly would be such a game changer for the field," she said. "There's so much data out there, but we don't have access to the vast majority of it."

Much of this awkwardness can be chalked up to differences in culture, says Hitinder Gurm, a U-M associate professor of internal medicine who has spent years straddling the line between data and medicine. He collaborates with Michigan Engineering's computer science professors on big-data tools for healthcare.

"There's a philosophical difference between what engineers consider research and what physicians consider research," he said. "Physicians want to look at an individual application, determine to a great degree how effective it is, see if we can improve it. To us, that's research. But computer scientists aren't excited about this. To them, research is developing a completely new way to do something. We need to figure out a way to bridge that gap."

BUILDING THE BRIDGE

The Precision Medicine Initiative (PMI), first announced by the White House in early 2015, aims to provide researchers and the public with a broad and deep pool of anonymized, widely accessible health data. Spearheaded by the National Institutes of Health, PMI is envisioned as a collective of a million or more volunteers who would provide a staggering variety of medical data: genomic profiles, electronic health record data, lifestyle information like exercise and diet habits – even blood and other biological samples, which would be collected and stored in a central facility.

The project's creators believe that the volunteer nature of the project could allay hospitals' and patients' privacy concerns by getting permission from each participant before they volunteer any information – they'd be able to volunteer as much or as little information as they choose. By enabling volunteers to donate their existing medical record data through their insurance provider or hospital, they plan to tap into the stockpile of data that's sitting unused at hospitals and other healthcare players. They'd

$$\min_{\theta} \frac{1}{2}\theta^T\theta + C\sum_{i=1}^{n}\sum_{t=1}^{m_i} log(1+e^{-y_t^{(i)}\theta^T \mathbf{x}_t^{(i)}})$$

$$\text{where } \Phi(\mathbf{x}_t^{(i)}) = [\mathbf{x}_t^{(i)}, \langle \mathbf{0}\rangle^{j-1}, \mathbf{x}_t^{(i)}, \langle \mathbf{0}\rangle^{T-j}]$$

$$\forall\, t \in \tau_j \quad \text{for } j = 1, 2, 3, ..., T$$

DOING THE MATH

Wiens' team used the optimization problem above to learn a predictive model that calculates a patient's daily likelihood of contracting a *C. diff* infection during a hospital stay.

They used multi-task learning to calculate a set of risk parameters ($\boldsymbol{\theta}$) by analyzing the electronic health records from a large set of hospital stays. Patient data ($\mathbf{x}$) included a variety of clinical information – some of which may change over time, such as patient location, vitals and procedures – and some of which remains the same, such as patient demographics and admission details. *C. diff* infection status was represented by y. The expression considers each day of the stay (t), taking into account that a person's status at admission matters less as the patient spends more time in the hospital. To reflect this, the risk parameters vary over the course of a hospital stay.

Wiens' group calculated the set of risk parameters for different time periods simultaneously by finding the set of values ($\boldsymbol{\theta}$) that minimize the objective function given above. Then, they used these parameters to build a model that produces a daily risk score, estimating a patient's individual probability of acquiring a *C. diff* infection.

also recruit new volunteers directly, who could take a medical exam and donate the captured information to the project.

If it works as planned, the PMI cohort could provide the sort of deep, detailed and consistent data that researchers like Wiens pine for. Funded with an initial grant of $130 million for fiscal year 2016, the project is in its early stages – a group of health care providers, medical records software companies and other experts are working to find the best ways to move forward.

William Riley, the director of the Office of Behavioral and Social Science Research at the NIH and a clinical psychologist by training, says the project is already leading to more collaboration between doctors and data scientists, but there's still a long road ahead.

"These aren't technical issues, they're logistical and policy issues – smoothing the way for hospitals, getting electronic health record vendors to make their new versions compatible. That takes time, but we're headed in the right direction."

U-M's School of Public Health, Institute for Social Research and the University of Michigan Health System are playing a role in solving some of those issues, working with Google and other partners to design some of the digital tools that will make data available to researchers and participants while keeping it safe. Goncalo Abecasis, the Felix E. Moore Collegiate Professor of Biostatistics and director of the Biostatistics Department in the U-M School of Public Health, says that determining precisely who should have access to which data, and presenting that data in a way that makes sense, will be key to U-M's role.

"The goal is to make sure scientists can ask questions about the role of particular genes," he said. "Google's expertise lies in making the database scalable and managing access, while our expertise lies in presenting data in a way that's easy to use and intuitive to researchers."

The project's goals are lofty, and Riley doesn't pretend it will be easy to get a massive and disparate group of doctors, hospitals, software providers and others to work together. But he thinks they recognize that the benefits are too big to ignore.

"All of a sudden, this healthcare data is in a form that engineers and computer scientists can use," he said. "Clinical researchers are beginning to see the value in that, but there's still a gap in the way different people think about answering these questions."

MAKING BIG DATA EVEN BIGGER

What could researchers do with the kind of dataset that Riley and the NIH are working to create? More. A lot more. In fact, computer scientists like U-M's Barzan Mozafari believe that helping doctors find better answers is just the beginning. They say that data could also help researchers ask better questions. Mozafari, an assistant professor of computer science and engineering, is working to build new database systems to churn through enormous stores of data and find unseen connections that could lead to new discoveries and whole new branches of medical research, in everything from cancer to pharmaceuticals.

"Sometimes scientists and doctors don't know what to look for, and I think that's this millennium's challenge, the million-dollar question," he explains. "We're trying to build a new generation of intelligent systems that are proactive, that can feed you hypotheses and find correlations. You can't replace scientists with machines, at least not soon, but the idea is that the machine should be able to suggest things to the scientist."

The trouble with mining healthcare data, says Mozafari, is that today's databases aren't designed to do a very good job of it. They're made for the business world, where data tends to be cleaner and researchers often know precisely what they're looking for.

Healthcare researchers often can't use existing data science approaches, largely because there's just so much healthcare data. It takes conventional systems too long to chew through it, and research has found that even short delays can disrupt the research process, causing a noticeable lag in creativity and idea generation. And the amount of data is growing faster than Moore's Law, so better processors aren't likely to provide a solution.

Also, healthcare data is messy. It contains thousands of variables, and many of them are often missing, incomplete, unreadable or recorded differently from one healthcare provider to the next. This trips up most databases, preventing them from providing good answers.

To get past these problems, Mozafari is designing a new kind of database system called "Verdict." It uses what's called "approximate queries." Instead of plowing through a massive dataset with a single query to find the most accurate answer, it conducts several, slightly less precise searches simultaneously. It then compares and carefully combines these queries into a single answer. The resulting answer is 99 percent as accurate as a traditional approach, but can be done up to 200 times faster. That could mean getting an answer in seconds instead of hours.

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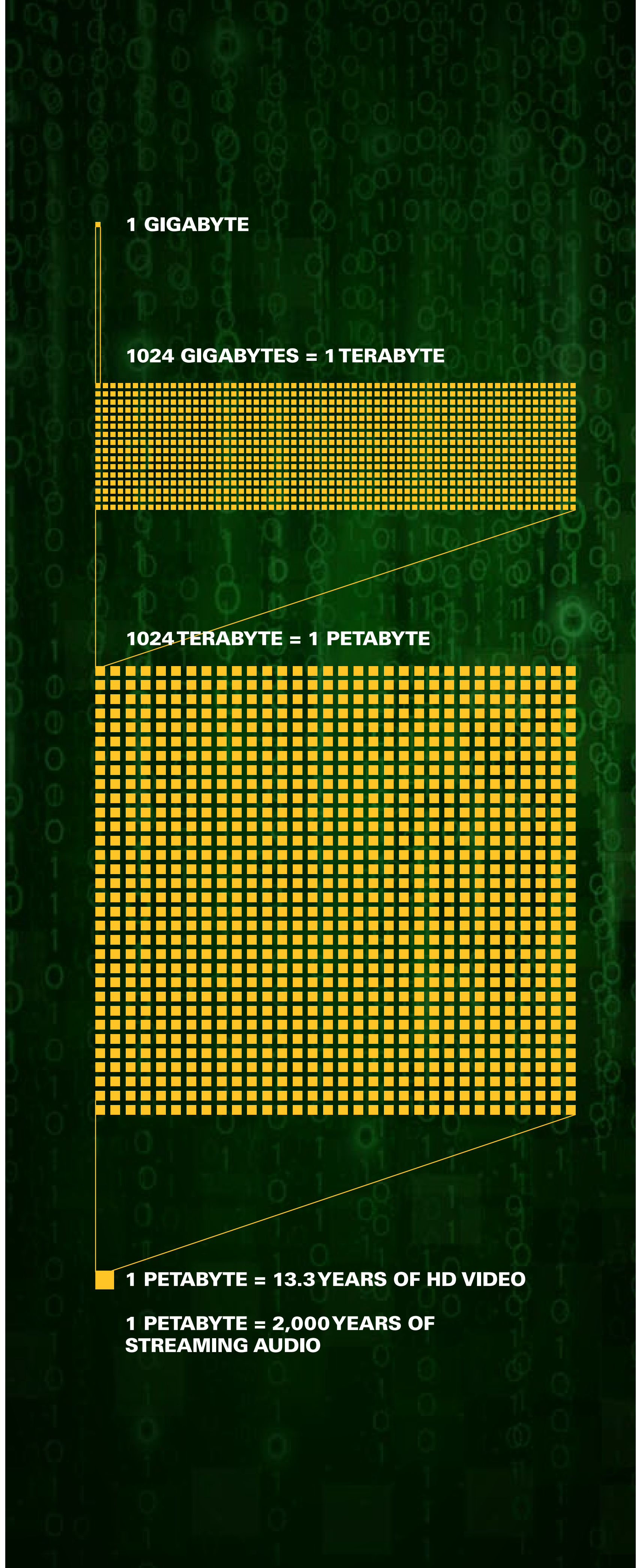
Comparing multiple queries also helps to compensate for missing or incomplete data, providing better answers with less irrelevant information. And the system learns from past queries, so it becomes more and more accurate as the research process wears on.

Mozafari says these speed improvements could transform the research process, powering automated systems that sift through hundreds or thousands of hypotheses looking for obscure connections and bits of information that no human could find.

"We're trying to hide the database plumbing so that it doesn't hinder the discovery process," he said. "When researchers can simply point the system at a lake of data, it's going to take us far beyond where we are today."

Mozafari is optimistic about the future relationship between engineers and healthcare, though he cautions that countries with more centralized healthcare systems have a head start in building a cohesive health data infrastructure.

"There are more well-managed, more efficient and more successful health systems in Europe. But we have many of the best data science researchers here in the U.S. They come from all over the world to work here," said Mozafari. "This is a huge opportunity. If we harness it."



A PETABYTE-SIZED PROBLEM: MANAGING THE DELUGE OF GENOMIC DATA

Genomic data is a key piece of the precision medicine puzzle it can help researchers understand why diseases strike certain people, provide insight into how a disease works and lead to more targeted medications. And researchers are getting better and better at using it.

"The amount of data we can collect and process is growing four-fold every year," said Goncalo Abecasis, the Felix E. Moore Professor of Biostatistics. "And unlike in the past, we can now look at entire human genomes. Ten to fifteen years ago, we could only look at a few genes, so we had to ask very narrow questions, and there was a lot of guesswork. Today we can see the entire genome and use that to look for correlations with disease."

But genomic data is ginormous – a single human genome takes up about 100 gigabytes of memory. That adds up fast when researchers are working with large numbers of patients, creating a vexing challenge for data scientists.

"Most campuses don't know what to do with this data," said Eric Michielssen, the Louise Ganiard Johnson Professor of Engineering at U-M. "If you have 10,000 patients, the data volume associated with their data is petabytes. That's millions of gigabytes. The storage and transport costs are incredible."

The costs are so great, in fact, that making copies of genomic data available to researchers often isn't practical – storing that new copy could cost hundreds of thousands of dollars.

The **Michigan Institute for Data Science (MIDAS)** is working to find a better way, enabling researchers to use and share data without creating multiple copies. The project's dual focuses are on finding less expensive ways to collaborate and on building new databases that can keep patient information safe even as it's made available to more and more researchers. You can learn more about their efforts at **midas.umich.edu**.

On the clinical side, Abecasis is working to gather secure, shareable genomic data for large numbers of patients. He's heading up two initiatives that are making more genomic data available to the researchers who need it.

The **Michigan Genomics Initiative** enables non-emergency surgery patients at the University of Michigan Health System to volunteer their genomic and electronic health record data, making it part of a data repository that can be used by researchers. The initiative has captured data from over 32,000 patients since it began. Abecasis says that 80% of eligible hospital patients choose to participate.

Genes for Good uses social media to collect health, lifestyle and genomic data from online volunteers. It also enables participants to compare their health information to other participants and use it to make more informed health decisions. Abecasis says the program has over 10,000 participants thus far. The program is free, and any United States resident who is 18 or older and has a Facebook account can participate. To sign up, visit **genesforgood.com**.

EXAM WEEK

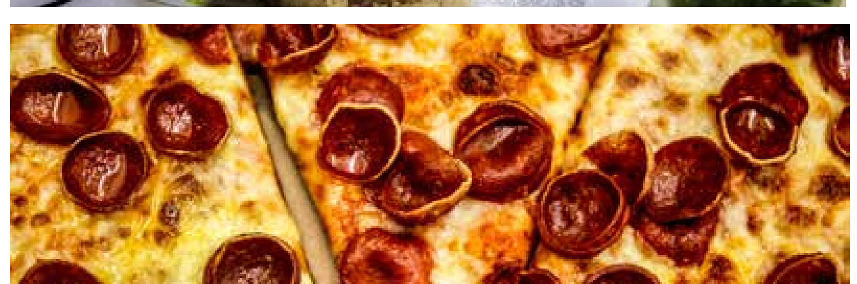
PHOTOS & CAPTIONS: JOSEPH XU

EXAMPLE: [A] [B] [D] [E]

The lights never turn off. Everywhere you turn, eyes are heavy as a tense silence pervades, punctuated by the sound of the frenetic race of fingers across keyboards and through notebooks filled with a semester's worth of notes. The air wafts through the stacks of books, thick with the smell of greasy and increasingly stale food, clothes that have been slept in for days on end, and the bodies that begrudgingly live through this existence. This is a rite of passage that all Michigan Engineering students face at the end of the semester as they prepare for their final examinations, living the extremes of vigor and fatigue, hubris and self-doubt, community and isolation, and frustration and elation – all within the period of just one week.

Students congregate in whatever available study spaces they can find, spanning across campus from the "UGLi" to the "Dude." There they spend multiple nights with each other, sharing stress-filled moments, meals and various means of procrastination that provide the ostensible balance.

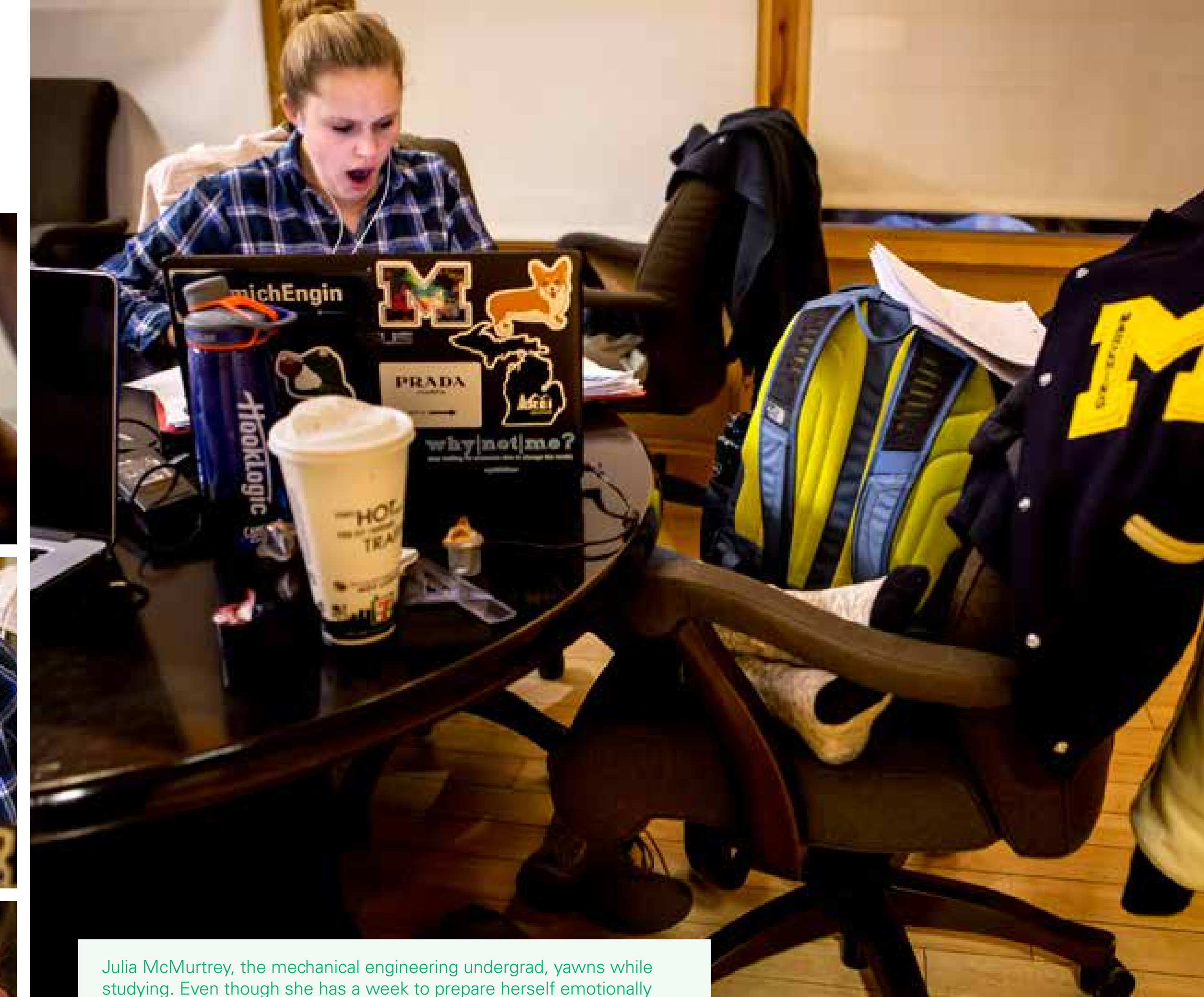
Ayat Maz gets his necessary fill of protein, carbohydrates and vitamin C from the chicken and vegetables he prepared at home. While Maz tries to remain health-conscious during finals, many others turn to the convenience and comfort of pizza and takeout food.



"I COULDN'T DO THIS WITHOUT THEM. YOUR FRIENDS ARE WHAT MAKE FINALS BEARABLE AND HELP YOU GET THROUGH IT WHEN YOU DON'T WANT TO."

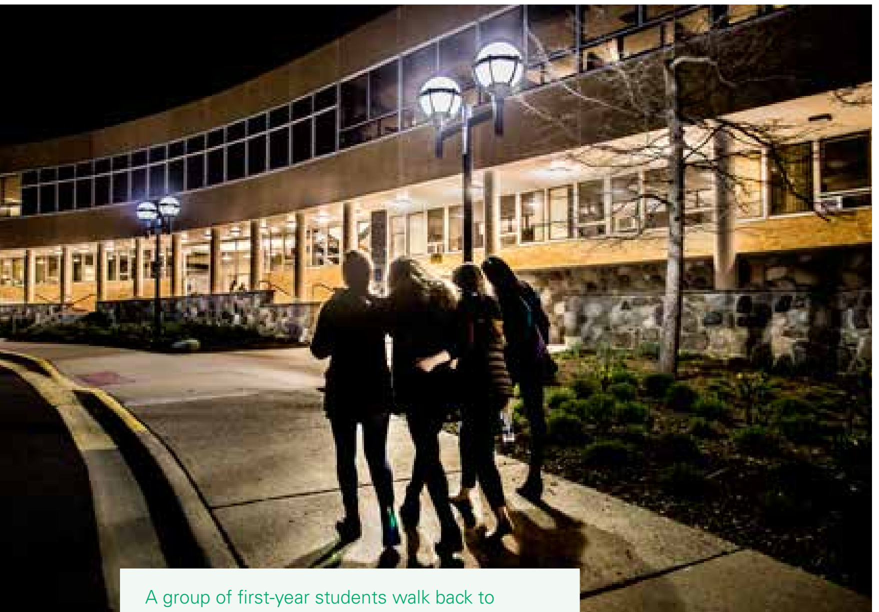
-JULIA MCMURTREY, ME BSE STUDENT

Bodies of students in various states of torpor can be found strewn across campus, making it difficult to distinguish between night and day. The only reliable clocks that students have are the pressing deadlines for their exams and final projects.

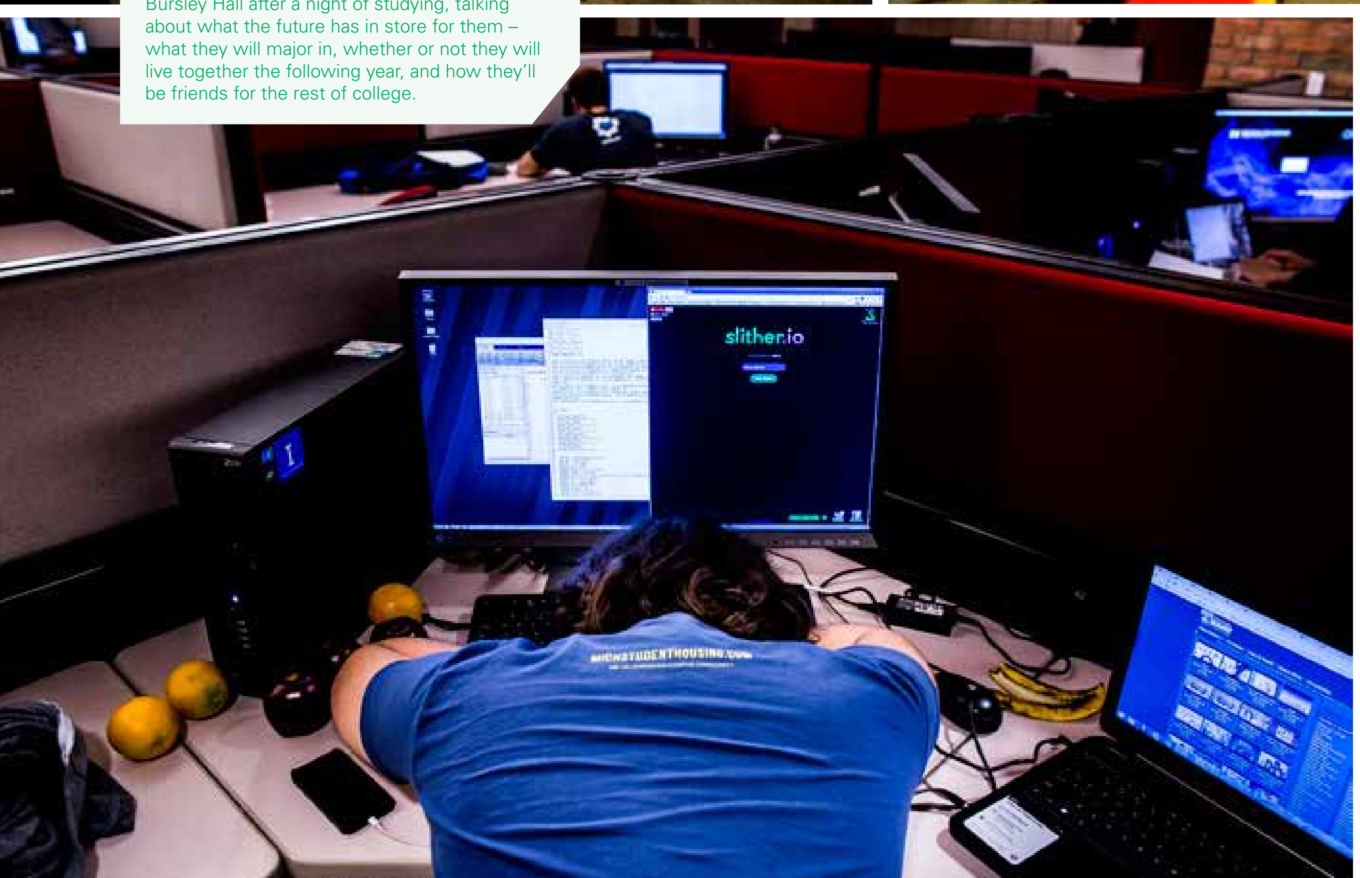


Julia McMurtrey, the mechanical engineering undergrad, yawns while studying. Even though she has a week to prepare herself emotionally and physically, there's still much stress and trepidation since she has to take all four of her exams during the last two days of finals.

"IT'S A LOT TO DEAL WITH ALL AT ONCE. YOU HAVE TO BE PREPARED AND MAP OUT HOW YOU'RE GOING TO GET IT ALL DONE OR YOU'RE GOING TO FAIL." -JULIA MCMURTREY



A group of first-year students walk back to Bursley Hall after a night of studying, talking about what the future has in store for them – what they will major in, whether or not they will live together the following year, and how they'll be friends for the rest of college.



Pame Martinez and Donald Richardson, Industrial Operations Engineering graduate students, finished their last project of the semester just minutes before the deadlines. They celebrate with a "fishbowl" at Good Time Charley's on South University Avenue. Others in the group include Abhilash Rao, Christian Abney, and Gary Piong.

"WHEN I SUBMITTED MY LAST PROJECT, I KNEW A JOURNEY WAS COMING TO AN END. I FELT PROUD AND A LITTLE MELANCHOLIC, BUT SUPER EXCITED TO CELEBRATE OUR BIG ACCOMPLISHMENT AND FINALLY CATCH UP ON SOME SLEEP."

-PAME MARTINEZ, IOE MSE STUDENT

VICTORS STEP UP

MICHIGAN ENGINEERS ARE STEPPING FORWARD TO TRANSFORM THE COLLEGE – AND THE WORLD – IN OUR $1 BILLION RESOURCE-GENERATION EFFORT

THE MUNSON LEGACY CONTINUES

An artist's rendering of the swing set at night

PHOTO: STOSS LANDSCAPE

Connecting with students – and finding ways to support them – has always been a hallmark of **David C. Munson Jr.**, the former Robert J. Vlasic Dean of Engineering, and his wife, **Nancy**. It's an inspiration that lives on at the College in a variety of ways.

Two prime examples are a new fund named in Professor Munson's honor that supports the Center for Entrepreneurship and its weekly entrepreneurship speaker series, and an endowed scholarship fund that will be used to support undergraduate scholarships named in honor of both Dave and Nancy. "These funds were established by a set of donors we have come to know well, and who we admire and deeply respect, which makes this all the more special for us," Munson said.

A fund dedicated to enhanced student support, he said, aligns well with both the College's needs and his own priorities.

"When I was an undergraduate, it was possible to earn enough over the summer to pay for tuition, and maybe even room and board. It was a time when state support for higher education was much higher. Well, that's no longer possible," Munson said. "To attend a superb institution like Michigan, many students need financial aid."

Dave and Nancy also have made a contribution of their own to the renovated North Campus Diag (the Eda U. Gerstacker Grove). The funds are intended for "high-tech" swing sets for students and other passersby to use. They will enhance a construction project intended to make the wide-open central area a more inviting and communal space.

The swings are dynamically coupled and are designed with motion-activated lighting. They will complement the new sand volleyball court and natural amphitheater. Munson said students expressed a strong interest in swings during the research phase of the project, so he expects this interactive version of a traditional swing set will be well received.

"I hope this is one element of the project that helps build our community," Munson said.

INVESTING IN MICHIGAN ENGINEERING LEADERSHIP

The students and faculty in the entrepreneurial ecosystem at U-M just got a boost.

Earlier this year, **Dixon Doll** (MSE EE '65, PhD '69) established the Dixon Doll Executive Director of the Center for Entrepreneurship Fund. Doll hopes it will help to "make more students and faculty aware of the importance of entrepreneurs in the technology ecosystem, and help them understand the critical success factors in building companies, and the personal attributes that venture capitalists look for in entrepreneurs."

Doll – who says his father, a teacher most of his life, instilled in him a passion for mentoring and encouraging others – recognized this opportunity "to put in place a program to inspire others, and to explain that if I did not have my Masters and PhD from Michigan I would never have had an opportunity to become deeply involved in the tech and VC industry."

Reflecting on the fund, Doll says that he's been "privileged and honored to have had the opportunity to be involved in the venture capital industry," and he wants to "try to let other people have the same good fortune that I had."

Doll started the first venture capital industry fund focused on telecom at Accel in 1985. He co-founded Doll Capital Management in 1996, which became the first Silicon Valley firm to invest in China. He has spent most of his professional life guiding and mentoring entrepreneurs, executives and investors in the computer, communications and internet industries and is considered by many as among the founders of Silicon Valley.

Entrepreneurship, Doll believes, drives technological change and job creation – which makes the world a better place. But it's "not at all easy for entrepreneurs who are trying to launch their companies to master all the things they have to do to create a successful company."

The Dixon Doll Executive Director of the Center for Entrepreneurship Fund should certainly help with that.

CIVIL, DESIGN & ANTHROPOLOGY

Three new funds will help students in need as they pursue degrees in civil engineering, design and anthropology. They are established with a $1 million bequest to the University of Michigan from the estate of **Stanton R. Cook**, former CEO of the media giant Tribune Company.

Cook left it to his longtime friend **Gretchen Hoenecke** (B.Des. '50, TeachCert '52) to choose how the bequest should be used. She created funds to facilitate the success of students who share her interests and those of her late husband **Karl Hoenecke** (A.B. LSA '54, MBA '55) and her grandfather, **Henry Earle Riggs**, a former chair of the department of civil engineering.

"Both sides of my family, the Riggs and the Hoeneckes, bleed blue," said Hoenecke. "I am just so grateful to be a part of honoring my family through this gift by my good friend Stanton Cook."

The Henry Earle Riggs Graduate Fellowship Fund in Civil Engineering will support graduate students in civil engineering while the Riggs Hoenecke Undergraduate Student Experience Fund in Anthropology will help students access study abroad experiences, international research trips and internships. These funds are established with $250,000 each.

Half of the bequest will go to the Riggs Hoenecke Scholarship Fund for Design, to support students who show talent in design, particularly graphic and industrial design.

A BOOST FOR BIOMED

Engineering and medicine are coming up with some of today's most promising health innovations. Now some of this partnership's most commercially viable ideas have a new resource to help get to market.

With a $3 million gift from the Monroe-Brown Foundation, the Monroe-Brown Seed Fund will award money to biomedical startup companies that are joint efforts between U-M's engineering and medical schools. Such seed grants are designed to accelerate the commercialization of biomedical research, to provide unique educational opportunities for researchers and students, and ultimately, to positively impact patient care.

The fund was developed under the guidance of **Robert Brown** (BSE Ind.E. '63), a Michigan Engineering alumnus and president of the foundation. It is a collaboration between the U-M College of Engineering's Center for Entrepreneurship and the U-M Medical School's Fast Forward Medical Innovation program. It will supply resources for the University's biomedical startup companies with marketplace potential.

The fund will invest in startup companies such as those developing medical devices, diagnostics, therapeutic delivery systems, health IT and digital health products. The money is expected to help attract and retain biomedical entrepreneurs and top-level researchers.

Big round of applause to seniors who have taken a pledge to give to the Michigan Engineering Fund (MEF)! Your pledges and gifts make an important contribution. Through both hard work and commitment for future support, you make Michigan Engineers the leaders and best.

SENIORS PLEDGE TO THE MEF

1 Seniors pledge to give any amount to the MEF once a year, for 5 years *after* graduation.

2 Seniors choose a fund in Michigan Engineering. That could be a department or a sponsored student organization/team. Their fund receives $250 from the MEF in their senior year. The more seniors take the pledge, the more money their organization/department will receive.

3 After those seniors graduate, they complete their pledge to the MEF.

The Senior Matching Pledge Challenge gives seniors a chance to be philanthropists at no cost to them while they are in school, increasing their impact and awareness of the MEF. And they help out sponsored student organizations and teams, departments and programs that enhance the Michigan Engineering student experience.

Find out more at http://umicheng.in/SeniorPledge

"WITHOUT THESE FUNDS, STUDENTS MIGHT HAVE NOT HAD THE OPPORTUNITY TO HAVE THE EXPERIENCE BUILDING A GREENHOUSE IN PERU, OR TEACHING COMPUTER SCIENCE IN SOUTH AFRICA ."

– Engineering Global Leadership Honors Program, one of many recipients of the challenge

PHOTO: JOSEPH XU

A SAFETY NET

Students helping students

The students in CARE are making strides toward their goal of a new emergency scholarship fund. One recent milestone was a meeting with U-M football coach Jim Harbaugh (front, fourth from left), who signed a helmet the group plans to auction off.

Julia McMurtrey remembers the moment in high school when her dream of attending Michigan came into reach in an instant. She was at a national competition for student leaders when she read the email on her phone: It announced a scholarship that meant her family could afford the tuition.

"I just remember crying. And at the same time I was crying, I was thinking, 'I can't look like a mess at the competition!'" McMurtrey said.

Her parents were going through a divorce that made their financial situation uncertain, and her family also needed to support her brother in college. Michigan did not seem like an option to her until that email came through.

The experience was a big influence on her. It's what motivated her to join a small group of other Michigan Engineering students to provide a safety net for fellow students who suddenly can't pay for school. McMurtrey, who is a senior studying chemical engineering, helped launch Cost Assistance for Resilient Engineers (CARE), an emergency scholarship fund that provides support to U-M engineering students in an unexpected financial crisis.

About half a dozen engineering students a year have something happen to their families, such as a death or a serious illness, that puts them in a financial bind. Suddenly their only choices may be to drop out or take on more debt on whatever terms they can arrange.

"When I got my scholarship, it was a very overwhelming feeling, because it meant that someone believed in me enough to support me," McMurtrey said. She can imagine what it is like for students whose support disappears. "That's completely outside of their control. And that's not fair."

CARE is still building. When it is big enough, the plan is to provide one-semester scholarships of $5,000 to $10,000. The first scholarship it awards may be $1,000 to $2,000, McMurtrey estimates.

The growth of the fund has been remarkable. A little more than a year ago, the students on the team faced the daunting task of raising $25,000 to endow the fund at a level that would allow CARE to make annual awards from the interest. McMurtrey said there were setbacks early on; it was hard to get their name out there, and some events fell through.

But the team rallied for last year's Giving Blueday, an event that became a huge turning point for them. During the annual U-M day of giving, which takes place on the Tuesday after Thanksgiving, CARE exceeded its $25,000 goal by more than $5,000. To take advantage of matching funds provided through the College, the students worked hard to attract donors. "We were overwhelmed by the generosity and support we received," McMurtrey said. "That's the moment when we kind of made it."

"The passion and dedication of this group of students was inspiring right from the start," said **Laura Rowe** from the College's Advancement office. "They had an idea, made a plan and let nothing stop them from achieving their goal of an endowed scholarship. I felt fortunate to have the opportunity to help them."

"'THOSE WHO STAY WILL BE CHAMPIONS' RESONATES A LOT WITH US."

Momentum has continued to build since then. Their success on Giving Blueday qualified them for a visit by U-M football coach **Jim Harbaugh** in the spring. Julia obtained a Michigan football helmet for Harbaugh to sign that they are planning to auction. And the group is gearing up for another Giving Blueday on Nov. 29.

The goal in the long run is to raise $1.5 million for the endowment, which would generate $67,500 in scholarships per year. This would meet the estimated need of five or six students each year.

To McMurtrey, anyone who chooses a course of study as difficult and with as much potential as a U-M College of Engineering degree deserves a chance.

"A family emergency should never alter your future," McMurtrey said. "We always use the quote by Bo Schembechler, 'Those who stay will be champions.' And that resonates a lot with us because everyone deserves the chance to stay and have that opportunity to pursue those career goals they had when they came into school."

A GIVING DAY FOR GIVING BLUE

Last year, Wolverines from around the world pulled together on a single day to support something they love. Giving Blueday – the University's annual day of giving on the Tuesday after Thanksgiving – was a great day to be a Victor for Engineering.

$4 million+

Amount raised university-wide to support engaged learning, faculty and research

352

Number of donors from the College of Engineering alone who contributed gifts of all sizes

$93,000

The total for one day by those 352 people. In addition, other gifts inspired by Giving Blueday topped $320,000 for a total of more than $415,000 and 371 gifts.

The impact of those gifts rippled out into the Michigan Engineering community. They helped students overcome financial crises and stay in school, supported student teams that develop sustainable solutions with communities around the globe, funded scholarships and much more.

Michigan Engineering students push themselves every day to build a brighter future for all of us. You know. You've been there. Nov. 29 is Giving Blueday – your chance to support the kind of experiences that make a Michigan Engineering education unique.

FIRST THERE WAS THE U-M TEACH-IN …
***THEN* THERE WAS EARTH DAY**

This photo was taken at a student rally held at the Diag during a four-day student-organized Teach-In on the Environment on March 11-14, 1970. The Teach-In featured at least 125 separate events – including a discussion about the future of the Great Lakes among an ecologist, a lakes scientist and an engineer. The great success of this marathon teach-in – attended by an estimated 50,000 people – fortified those who were organizing the first nationwide Earth Day, which would be held just five weeks later, on April 20. Earth Day has since played a major role in heightening public awareness and shaping environmental policy – but the U-M Teach-In that preceded it offered the first proof that a mass educational effort on this issue, if executed properly, could attract the public's interest.

In 2017, the University of Michigan will commemorate its 200th anniversary. As part of this, Michigan Engineering is presenting the Michigan Engineering Bicentennial Project, a series of stories about its long commitment to educating future leaders, discovering new technologies and finding solutions that impact the world.

UNIVERSITY OF MICHIGAN BICENTENNIAL

ALWAYS INNOVATING. FOREVER VALIANT.

200 YEARS & COUNTING
THE MICHIGAN IMPACT

World War II Navy units in formation at Ferry Field

PHOTO: Bentley Historical Library

EXPERIENCE / 1940s

WARTIME TRAINING

Michigan Engineering participated in a University-wide World War II initiative to accelerate military research and education by preparing and instructing Naval officers for Construction Corps duty, training aircraft inspectors and pilots and engaging in research to improve the design and manufacture of military equipment.

In all, the Engineering Science and Management War Training Program prepared more than 12,500 men and women for immediate service. It enrolled 1,256 men in the Army Specialized Training Program, while 3,513 received training in the Navy V-12 Program and 6,885 civilians were graduated on an accelerated basis in regular degree programs.

And off to war they went.

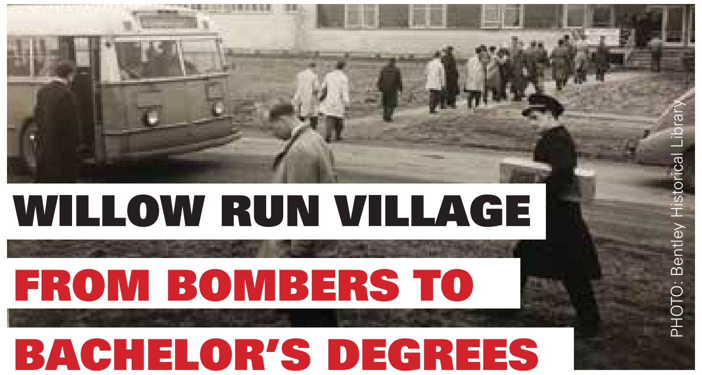


PHOTO: Bentley Historical Library

WILLOW RUN VILLAGE
FROM BOMBERS TO BACHELOR'S DEGREES

After the war, thousands of returning veterans enrolled at Michigan under the GI Bill – which caused an immediate housing crisis. Single dorms were turned into doubles, doubles were turned into triples and a hastily constructed village of trailers sprang up near Hill and Packard. But it wasn't enough.

University planners found a solution in Willow Run Village – a wartime housing project 12 miles east of campus. Originally built to house workers at the massive Willow Run bomber plant, the complex found itself with extra space after bomber production ended. U-M leased the empty apartments, a bus service was set up to shuttle students to and from campus and 1,200 veterans moved in.

The simple wooden row houses were anything but fancy – streets were dirt, walls were thin and heat came from a coal stove in the living room. But at $14.50 per month for a two-bedroom apartment, the price was right and veterans formed a close-knit community.

To see more Willow Run Village and wartime campus photos on the Michigan Engineering Bicentennial Project website, scan this page with the decoder in the One Cool Thing app.

LETTERS FROM THE FRONT

During the war, students and alumni stationed all over the world used a U.S. military system called V-Mail to stay in touch. Every letter to and from the front was censored, then photographed and recorded on microfilm.

The film was shipped by plane to a post office or military post near its destination, blown up to 60 percent its original size, then printed and delivered. The system reduced 37 bags of letters to a single bag of microfilm, saving valuable space for the transport of military supplies.

U-M-affiliated men and women sent hundreds of V-Mail letters to Michigan Alumnus magazine, which published them in a special section. Here are just two of these many letters:

Dear [Engineering] Professor [R.E.] Townsend:

I was very glad to get your letter a few days ago, and find out that you and "the gang" at Michigan are getting on about as usual, in spite of restrictions that war necessitates.

…This lack of mail caused much weeping and gnashing of teeth…. [T]wo of the fellows found out they were the proud fathers of baby boys! …Lack of mail is especially hard on the married men, some of whom write their wives more than once a day…

Best regards,
George Bachman, '43e

…………………………

Dear Editor:

We are finally ready to believe the official confirmation that hostilities have ceased… Yesterday came the pay-off. An order was issued that helmet liners could be worn in lieu of steel helmets. When that happens – it's over.

Wars seem to end in a queer way. … The men at the front who did the fighting should be the ones to celebrate the war's end. … At first glance, there didn't seem to be a bit of difference in them. …

Once convinced, however, there was a subtle change noticeable in men. To one who knew them, they were more relaxed, readier to laugh, and the strain in their eye was replaced by a dreamier "thinking-of-home" look.

Sincerely yours,
Pfc. Lawrence E. Girton, e'43-'44

PHOTO: Bentley Historical Library

IMPACT | 1950s

WOLVERINES IN SPACE

By the time Sputnik circled and beeped its way around the globe in 1957, Michigan Engineering was an established leader in the Space Race. Five U-M students would orbit the earth and three would go to the moon. Two separate NASA flights would launch into space with all-U-M crews aboard. And on June 3, 1965, Gemini 4 would launch NASA's first all-U-M crew: Edward White and James McDivitt, both of whom earned Michigan Engineering degrees in 1959.

But Apollo 15 – which blasted off on July 26, 1971 – would top that feat, with an all-U-M crew consisting of James Irwin, Al Worden and David Scott (pictured above). The fourth mission to land men on the Moon, Apollo 15 was the first to use NASA's new Lunar Roving Vehicle. The vehicle gave astronauts new ways to observe the lunar surface, survey and sample lunar material and surface features, conduct surface and in-flight experiments and take photographs while in orbit.

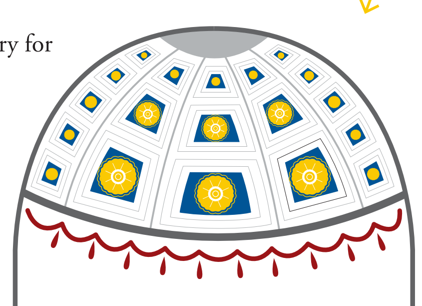
QUIRKY | 1920s

OSU GOES MAIZE AND BLUE

Maize and blue are not popular colors at Ohio State. So why, if you look closely, will you find that the upper rotunda at Ohio Stadium (also called The Horseshoe) features maize flowers against a blue background? Legend has it that a wager was placed on the outcome of the October 21, 1922, "Dedication Game" – the first matchup between the U-M and Ohio State football teams at the then-new stadium.

The Wolverines pounded the Buckeyes, thanks largely to the play of tight end, defensive end, kicker – and engineering student – Paul Goebel. Though he'd thrown out his knee the year before and was playing with a brace made from a crude steel hinge, Goebel kicked a long field goal, recovered a fumble, blocked a punt and generally wreaked havoc on OSU's defense all game long.

Goebel's efforts led to a 19-0 victory for U-M. And some say that the lost bet forced OSU into the maize and blue design that graces The Horseshoe's upper rotunda to this day.



QUIRKY | 1900s

MEET THE VULCANS

Michigan Engineering students founded the Vulcan Society in 1904, seeking what they described as "a good hearty relationship" with faculty and fellow students. In 1915, the Vulcans helped to develop the honor code that Michigan Engineering still uses. Today, they carry on other traditions as well, such as helping those in need with scholarships and other assistance.

In earlier times, new Vulcans (called "neophytes") underwent an elaborate initiation that began with being rounded up outside of town, then marched back to the steam tunnels beneath central campus. There, they might have been chained together and doused with grease and motor oil in a nod to engineering's mechanical origins. The Vulcans' activities were well-known and often photographed until the 1970s, when social pressures caused the Vulcans to change some of their ways.

Membership in the Vulcans is largely kept secret, and is exclusive to those who possess the group's hallowed "Four Qualities:" leadership, responsibility, integrity and humility. Perhaps that's why the Vulcans' ranks have included some of the most prominent student and faculty leaders in Michigan Engineering history.

PHOTO: Bentley Historical Library

Vulcans and other engineers playing the popular game of Pushball circa 1910

PHOTO: Bentley Historical Library

IMPACT | 1960s

THE FIRST WORKING HOLOGRAM

In 1952, twenty-five-year-old Emmett Leith was conducting highly classified research at Michigan's Willow Run Laboratories using a novel process that mixed and recorded radar waves onto photographic film. This early work laid the foundation for modern holography, a technology that's integral to fields from medical imaging to data storage and entertainment.

WHAT'S A HOLOGRAM?

A hologram is a three-dimensional image that is "indistinguishable from the original object itself," as Leith once said. Achieving this effect would take creativity, intuition, experimentation – and a bit of luck.

Dennis Gabor of the Imperial College London had first introduced the concept in 1947, but for various reasons, his work had gone dormant. Leith had been intrigued by the challenge and novelty of holography, but his other work kept him too busy to experiment with it until 1960, when Willow Run hired Juris Upatnieks as a new research assistant. At that time, the pair began their work using Leith's radar-based signal modulation theory.

THE SOLUTION

Leith and Upatnieks (pictured above) tried to improve the fuzzy resolution of Gabor's holograms, and to solve the mysterious "twin image" problem that had dogged earlier attempts. The twin image solution came when the team added a second beam to the recording process, combining two light signals into one holographic image and eliminating the second, unwanted image that had baffled other scientists.

The solution to sharpening the hologram's resolution came in the form of a laser. Another team at Willow Run was experimenting with one of the new machines, and Leith and Upatnieks eventually talked their way into borrowing it.

The new, more precise light source was a dramatic improvement over the mercury lamps that were used for earlier holograms. It enabled the team to optimize the system to produce crisp, three-dimensional reconstructions of the original objects.

ONE COOL THING

bicentennial.engin.umich.edu

For these and other Bicentennial stories, use your decoder (see p. 9) or type in the URL above to visit the **Michigan Engineering Bicentennial Project website.**

We'll be adding at least one new item every week through the 2017 Bicentennial, so be sure to return to the site often or sign up to receive emails for more Impact, Experience, Quirky and other Bicentennial stories.

The Michigan Engineering Bicentennial Project is dedicated to everyone who has contributed to Michigan Engineering's history – and to all those who will.

1817 M 2017

UNIVERSITY OF MICHIGAN BICENTENNIAL

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THE RACE AGAINST ZIKA

Richard Schwartz (right) discusses the production of the Zika vaccine with Matt Westerman (left), associate director of manufacturing at Leidos Biomedical Research, Inc., at the production plant.

U-M ALUM HEADS PRODUCTION OF PROMISING NEW VACCINE

Responding quickly to the Zika outbreak has been a top priority for the National Institutes of Health's Vaccine Research Center (VRC) – especially after the Ebola vaccine's clinical trials in Africa began just as the outbreak was drawing to a close. They began clinical trials of a Zika vaccine in August, just a year and half after the outbreak was identified in Brazil. And U-M alum **Richard Schwartz** (BSE ChE '81, MSE '89, PhD '91) led the effort to mass-produce enough of the vaccine to start clinical trials – and do it quickly.

"This is a problem that could impact almost every one of us in our lives and in our families at some point, if not immediately then in the future. We need to solve it, and a vaccine is the only way that's going to happen," said Schwartz.

The VRC brought Schwartz on in 2008, after nearly two decades of process leadership in pharmaceutical companies. As the head of the Vaccine Production Laboratory, his projects have included Ebola, Marburg, influenza and HIV.

Schwartz's team – and the VRC in general – made faster progress on Zika than it did with Ebola, in large part because Zika is so similar to West Nile. The VRC's prior clinical trial for West Nile suggested that a relatively easy-to-make vaccine, composed of DNA rings called plasmids, could be effective against West Nile, and the team believed that a similar vaccine could work against Zika.

Unlike a virus-based vaccine, plasmids are non-infectious and have a good safety record in clinical trials. That can shorten the safety testing – and it gave Schwartz's team a head start.

While some vaccines require months of puzzling to find the safest, most efficient production process, the Zika vaccine could be made with the same process used for West Nile, using *E. coli* bacteria as DNA factories and then extracting and purifying the plasmids.

"If we were to make a live or inactivated virus vaccine, development would be much more extensive and take months to years," said Schwartz. "One of the great things about the plasmid technique, especially in these outbreak type situations, is that it's really quick to get to the clinic."

The VRC's Zika vaccine contains DNA sequences that instruct cells to make proteins that appear on the surface of the Zika virus. When immunized, the body produces harmless particles that bear these proteins. The immune system then makes antibodies that target the proteins, which should help it block a Zika infection.

The DNA plasmids break down over the course of a few days but the antibodies remain, ready to fight the real virus if it ever shows its face.

Testing of the Zika vaccine in mice was promising – it showed that the mice did in fact produce antibodies against the Zika virus. Once this testing was complete, the vaccine moved to a pilot plant for production.

At the pilot plant, one of the biggest challenges Schwartz's team faced was how to get as much plasmid DNA as possible out of each batch of vaccine (scan this page with the Decoder in the One Cool Thing app to see a video of both the lab and the plant during the Zika production run). They spent a month and a half on the problem, assigning one of the lab's chemical engineering PhDs to spot bottlenecks and increase the productivity.

PHOTOS: Joseph Xu

"As a chemical engineer, your first class is mass balances. And it stays with you for the rest of your life," said Schwartz. "You always need to know where your product is going."

They discovered that while roughly 60 percent of the initial plasmids disappeared during purification, the biggest gains could be made in plasmid production. *E. coli* bacteria are capable of increasing by a factor of $1.3x10^{36}$ in 40 hours, but they need just the right amount of food to do it. Too little, and they don't reproduce to their full capacity. Too much, and they overeat, producing toxic metabolites that prevent peak growth and productivity. Once they stopped overfeeding the *E. coli,* the amount of plasmid they collected increased five-fold.

"That's pretty good," said Schwartz. He reckons that the yields could be even higher with further tweaking of each step, but he keeps scope in mind. "We don't have to make millions; we have to make thousands for our clinical trials."

The Phase 1 clinical trial underway is mostly intended to ensure that the vaccine is safe. In early 2017, the vaccine may be ready for Phase 2, involving hundreds or thousands of people in multiple countries, including Brazil. This trial is intended to quantify the immune response of vaccine recipients and hopefully show vaccine efficacy.

Phase 3, which could begin in 2018, would need to show that people who received the vaccine were significantly less likely to get Zika than an unvaccinated person. Phase 3 might also include trials in pregnant women. Schwartz says that safety problems are unlikely with a plasmid vaccine.

Now that the Zika vaccine has started clinical trials, all that's left for Schwartz to do is make enough for the clinical trials and hope it will work. And figure out how to produce the next vaccines – for developing threats such as chikungunya or long-standing challenges like influenza and HIV.

Schwartz shows a miniature bioreactor, used in his lab for small-scale tests exploring how to grow viruses and bacteria for vaccine production.

MAKING THE ZIKA VACCINE

Producing the plasmid

A 100-liter fermentor

1. Thaw the 1 mL vial of *E. coli* bacteria that contain the Zika plasmid.
2. Grow the bacteria in a fermentor for 40 hours, at 30 degrees Celsius. They increase by more than 10 million-fold, reproducing the plasmids along with their own DNA.
3. Increase the temperature to 42 degrees Celsius for the last eight hours of fermentation. At this temperature, *E. coli* pour more energy into producing plasmid DNA than they do reproducing.
4. Harvest the *E. coli* from the 100-liter fermentor.
5. Break open the *E. coli* cells to release the plasmid DNA.

Purifying the vaccine

The harvested fluid resembles chocolate milk and is about 25 percent *E. coli* by weight.

1. Filter to remove large detritus, such as fragments of cell wall.
2. Run the fluid through a column that slows down small contaminants, such as DNA fragments and proteins. Collect the fluid that contains the plasmid and run through a second column.
3. Weed out bad plasmids – those that did not close into rings or coil properly.
4. Remove fever-inducing toxins and proteins produced by *E. coli.*
5. Filter. Vaccine is now sterile and 95 percent pure.

Packaging for clinical trials

Vials awaiting the Zika vaccine for clinical trials

1. Adjust concentration of plasmid and sterile filter.
2. Fill vials, stopper and seal.
3. Inspect, label and freeze the vials of vaccine.
4. Test and release the final product.

PHOTO: Courtesy of Ernst Mayer

PRIME NUMBER PROWESS

In a record-shattering display of raw mathematical power, a group of enthusiasts including **Ernst Mayer** (BSE AeroE '85, MSE '87, MA '91, PhD '93) has discovered a new world-record prime number. At over twenty-two million digits, the number is over five million digits larger than the previous record-holder, which the group discovered in 2013.

The group found their number earlier this year by multiplying 74,207,281 twos and then subtracting one. Verifying the number as prime took 31 days of non-stop computing on an Intel I7-4790 CPU.

Named GIMPS (that's short for Great Internet Mersenne Prime Search), the group studies a special class of prime numbers called Mersenne primes. They've been using freely available software to find ever-larger Mersenne primes since their founding in 1996, and have discovered all fifteen of the largest known Mersenne primes.

Mayer is already working on his next feat – verifying the world's largest known Fermat number, which weighs in at more than 2.6 billion digits. That's over 100 times larger than their newly-discovered Mersenne prime.

"Folks like me … who are not doing nuclear weapons design, climate modeling or high-frequency stock trading don't get dedicated access to true 'big iron' supercomputers, so this is a major challenge," he said. "I optimistically estimate that the needed compute power will become available around roughly 2025. In the meantime, there is still lots of coding and number-crunching work to do!"

MINING ASTEROIDS

Before **Hannah Goldberg** (BSE EE '03, MSE '04) took the job as senior systems engineer at Planetary Resources Inc., the business was so secret, its founders couldn't even explain it.

"At that point it was about trust and a personal connection," Goldberg said. She knew and greatly respected the pair from her time at the Jet Propulsion Laboratory. So when they finally revealed that they wanted her to work at their new asteroid mining startup, she agreed.

The venture is much more public now, and has grown from five people when she started in 2012 to about 40 today. Its long-term goal is to unlock the economy of space by exploring and mining valuable resources in asteroids. Sound impossible? Depends on the approach.

"We've done a good job of breaking up this crazy challenge into smaller challenges, and tackling them one at a time," Goldberg explained during a recent recruiting trip back to campus.

She said their focus right now is near-Earth missions, testing the basics to make sure they work. Later, they'll venture into deep space – a realm that, until recently, was reserved for NASA and the European Space Agency.

"Technology is reaching a point where it is more feasible for others as well," she said. "The entire industry is changing."

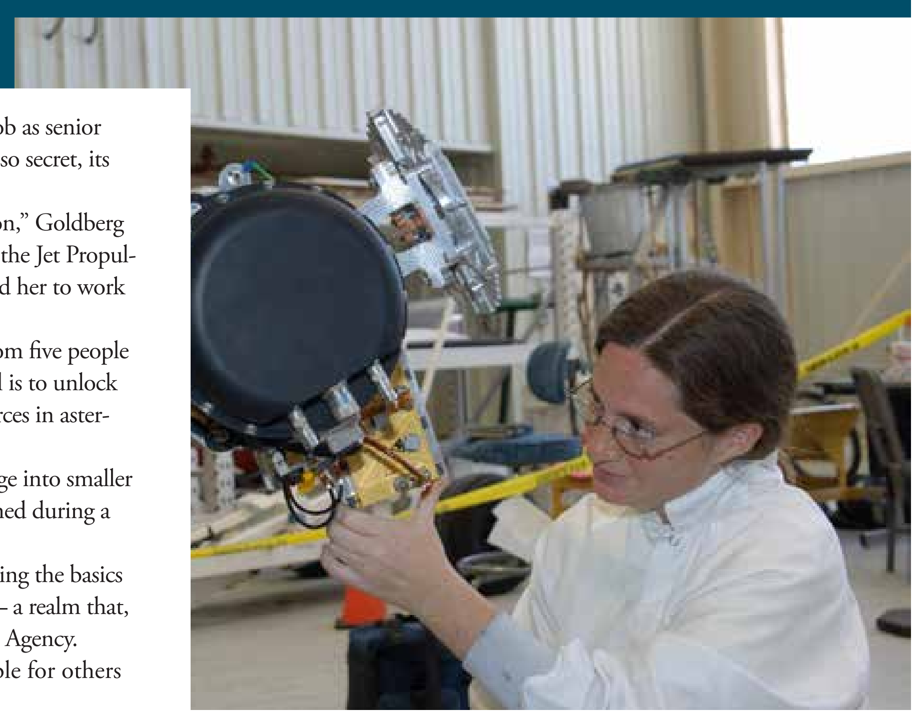

PHOTO: Courtesy of Hannah Goldberg

MI BUSINESS IS HIS BUSINESS

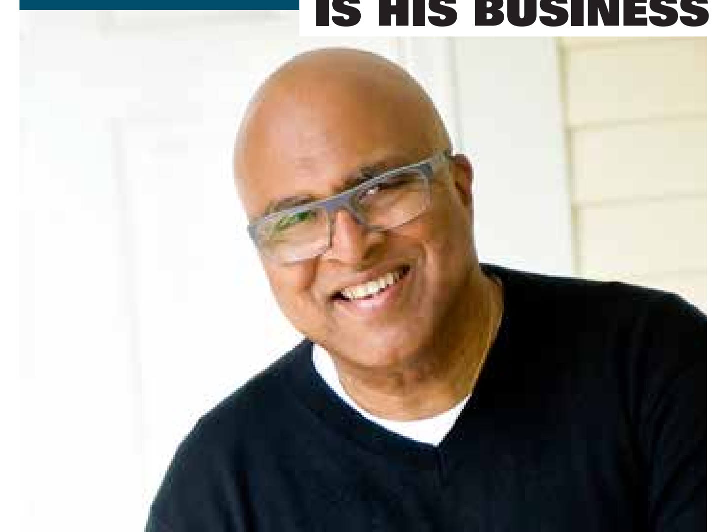

PHOTO: Meghan Lafferty

When entrepreneur and philanthropist **David Tarver** (BSE EE '75, MSE '76) moved back to Michigan in 2007, his home state was suffering. Cities like Detroit and Flint had no shortage of problems awaiting creative solutions, but people struggled to rally the resources that would turn their ideas into action. So Tarver founded the Urban Entrepreneurship Initiative (UEI) Inc. in 2014. UEI helps aspiring entrepreneurs tackle urban problems with innovative, sustainable and profitable business solutions.

"Solving these problems requires a combination of awareness, motivation and capability," Tarver said at the 2015 Urban Entrepreneurship Symposium. "And often, those three things don't exist in the same people, or even on the same team."

Tarver is no stranger to the impact people can have when they commit to a common goal. In 1983, he and two colleagues from AT&T Bell Laboratories started a tech company in Tarver's New Jersey basement. Twelve years later they sold the company, Telecom Analysis Systems, for $30 million.

Tarver would go on to establish a nonprofit focused on improving academic performance and opportunities for the children of his Red Bank, New Jersey, community. He has since returned to Michigan, where he has taught undergraduate classes at the U-M Center for Entrepreneurship since 2013. He is the 2016 recipient of Michigan Engineering's Distinguished Alumni Service Award.

A UNICORN GOES PUBLIC

PHOTOS: Courtesy of Twilio

Quartz called it "the most interesting tech IPO of the year."

In June, Twilio, a $1 billion cloud communications startup founded by three U-M alumni, went public, bringing in $150 million. The company was launched in 2007 by **Jeff Lawson** (BS CS '03), **Evan Cooke** (MS CS '04, PhD '07) and **John Wolthuis** (BGS '98).

Twilio is an application programming interface, or API, that lets developers easily add text, voice and video messaging to their apps. Boasting a long list of high-profile clients, Twilio makes it possible to communicate with your Uber driver or Airbnb host, for Home Depot to connect customers with contractors, for the Red Cross to find local volunteers and for WhatsApp to verify users' identities.

In 2015, Twilio became one of the rare startups to raise more than $1 billion – a "unicorn" in tech parlance. Today, it serves more than one million developers across the globe, operates in 22 data centers and claims to reach nearly every phone on the planet.

Twilio's founders at the company's IPO. From left to right: John Wolthuis, Jeff Lawson and Evan Cooke

Have a story for consideration in the next issue's Alumni Notes? Use the Decoder in the One Cool Thing app to share your submission. See page 9 for details on the app or email us at MichiganEngineer@umich.edu.

IN MEMORIAM

1940s

'40 Frank M. Conway 12/11/15
'40 John H. Flickinger 3/29/16
'40 Roger B. Peterson 4/21/16
'40 George R. Olding 5/7/16
'41 Charles N. Hagar 12/10/15
'41 Jerold J. Benavie 2/10/16
'41 Philip R. Mueller 3/2/16
'41 Robert P. Kimball 5/12/16
'42 Jack E. Linden 3/19/16
'42 Stuart W. Churchill 3/24/16
'42 Glidden S. Doman 6/6/16
'42 Peter A. Weller 6/15/16
'43 William T. Sullivan 2/17/16
'43 Donald M. O'Neill 3/20/16
'43 Jack Kuipers 4/27/16
'43 L. William Sessions 5/13/16
'44 Richard J. Bard 5/1/16
'44 Henry L. Schmidt 6/10/16
'44 John A. Riopelle 6/17/16
'44 James H. Weikel 7/13/16
'45 Robert B. Peck 1/23/16
'45 Joyce Van Tuyl 3/26/16
'45 John W. Ittner 5/16/16
'45 Hugh M. Wanty 7/6/16
'46 George W. Roberts 7/10/15
'46 Richard Kaplan 2/26/16
'46 Warren R. Pafford 5/8/16
'46 Robert A. Butters 5/27/16
'47 Guy Borden 7/3/15
'47 Donald E. Hildebrandt 11/25/15
'47 Glenn H. Bulthuis 1/12/16
'47 William C. Breen 3/4/16
'47 William N. Koeller 4/11/16
'47 Curtis V. Main 4/13/16
'47 Fred C. Matthaei 6/2/16
'47 Gilbert B. Silverman 6/13/16
'48 Clifford W. Straitor 8/19/15
'48 Douglas D. MacLeod 10/25/15
'48 Milton D. David 1/26/16
'48 John R. Hesse 4/3/16
'48 Norman N. Breyer 4/29/16
'48 Jack D. Zuiderveld 5/11/16
'48 Julian C. Renfro 5/12/16
'48 Lawrence R. Albright 5/13/16
'48 Marshall H. Damerell 6/27/16
'49 David L. Poindexter 7/3/15
'49 Anthony J. Neuwirth 9/9/15
'49 Conrad M. Ladd 9/26/15
'49 E. Ray Gordon 11/6/15
'49 Roland C. Bostrom 11/25/15
'49 Robert A. Rossi 2/1/16
'49 Claude E. Rudy 2/10/16
'49 L.W. Martin 2/25/16
'49 Max N. Clyde 3/1/16
'49 David W. Leyshon 4/8/16
'49 Donald D. Autore 7/10/16

1950s

'50 Ben Schulkin 7/2/15
'50 Raymond W. Fleischer 8/25/15
'50 Frank P. Crotser 9/9/15
'50 Clare R. Weaver 9/15/15
'50 Dean J. MacGregor 10/11/15
'50 Douglas D. Peden 10/30/15
'50 Calvin R. Srock 10/30/15
'50 Gail V. Slocum 1/22/16
'50 Peter G. Schmidt 2/4/16
'50 Daniel C. Probert 2/21/16
'50 William E. Camping 2/22/16
'50 Donald G. Smillie 2/24/16
'50 Rolf W. Ramelmeier 2/29/16
'50 George E. Karres 3/8/16
'50 Joseph W. Comstock 3/21/16
'50 Donald G. MacLean 3/26/16
'50 Harry A. Fry 3/27/16
'50 Carl I. Snider 4/20/16
'50 Robert E. Dieter 5/7/16
'50 John R. Chester 5/22/16
'50 Morton T. Eldridge 5/25/16
'50 William R. Upthegrove 5/25/16
'50 Thomas W. Fritchek 6/25/16
'50 Earl G. Forbush 7/1/16
'51 Eugene Pulgini 8/31/15
'51 Alan H. Molof 10/22/15
'51 George D. Pfaffmann 11/22/15
'51 Donald R. Medwedeff 1/25/16
'51 Thomas R. Elmblad 1/30/16
'51 Robert J. Bickett 2/24/16
'51 Richard F. Buchholz 5/1/16
'51 Richard G. Walterhouse 5/12/16
'51 Joseph F. Marmo 5/23/16
'51 John E. Powers 6/10/16
'51 John L. Torresen 7/15/16
'52 Russell J. Osterman 1/1/16
'52 Don J. Arneberg 1/20/16
'52 Quinten E. Ward 2/11/16
'52 Richard D. Dykman 3/13/16
'52 Edward Hudock 4/4/16
'52 Robert P. Williamson 4/26/16
'53 James A. Woodard 12/22/15
'53 Charles W. Beadle 3/7/16
'53 Robert K. Erf 3/21/16
'53 George M. Wallace 4/28/16
'53 Carl H. Ulbrich 5/23/16
'54 Ellen C. Tyroler 5/6/16
'54 Joseph Tiratto 5/6/16
'54 Ronald E. West 5/23/16
'54 Henry A. Domian 6/25/16
'55 Stanley B. Koehler 8/26/15
'55 Paul K. Trojan 6/28/16
'55 David E. Basket 6/29/16
'55 James L. Oom 7/1/16
'56 Ian A. MacDonald 7/14/15
'56 Lee E. Allgood 11/4/15
'56 Wayne C. Thiessen 12/25/15
'56 Donald A. Olson 4/13/16
'56 Chi Shiwing Cheng 6/6/16
'57 Philip B. Allen 2/14/16
'57 Yue C. Yang 2/18/16
'57 Charles P. Melfi 2/24/16
'57 Alfred A. Szemborski 5/3/16
'57 Bernard D. Campbell 6/25/16
'57 Alvin J. Norris 7/5/16
'58 Chimanbhai S. Patel 2/3/16
'58 Dale E. Briggs 3/17/16
'58 Larry L. Kole 4/25/16
'58 James C. McCarty 5/25/16
'59 Aelred F. Ahles 12/1/15
'59 Thomas O. Calvit 1/10/16
'59 Frank E. Bitonti 1/17/16
'59 Beverly S. Shilling 1/20/16
'59 Donald F. Reeves 2/8/16
'59 Robert H. Marks 2/18/16
'59 Douglas D. Orvis 4/11/16
'59 Bryan Betz 4/28/16
'59 Robert F. Fell 5/14/16
'59 Walter H. Schmidt 6/22/16
'59 Thomas S. Emerson 7/16/16

1960s

'60 James C. Fox 12/23/15
'60 Leonard M. Brush 1/15/16
'60 Leroy E. Medendorp 3/28/16
'60 Stuart F. Gordon 5/16/16
'60 Merwin W. Hemphill 7/7/16
'61 James K. Dabney 1/15/16
'61 George E. Murdock 4/14/16
'61 Jesse D. Hellums 6/26/16
'62 Swamidas K. Punwani 12/14/15
'62 Stephen J. Derezinski 12/24/15
'62 Robert J. Mull 4/21/16
'62 Robert F. Hand 6/27/16
'63 Gerald J. Montgomery 12/16/15
'63 Kenneth W. Lyon 1/4/16
'63 Walter A. Hubbard 1/9/16
'63 William R. Jeffries 5/24/16
'63 Stanley L. Piatkowski 6/3/16
'63 Dennis A. Kross 6/3/16
'64 Kenneth O. Cogger 8/15/15
'64 Robert I. McCullough 2/16/16
'64 Tsung Y. Na 3/25/16
'65 John T. Howell 2/25/16
'65 Robert K. Nicholson 5/14/16
'66 Jack E. Kaitala 7/11/15
'66 Walter W. Broad 2/3/16
'66 Richard S. Bullock 2/5/16
'66 Thomas B. Auer 5/31/16
'66 Fred T. Shen 5/31/16
'66 Daniel E. Kowler 7/2/16
'67 Tse-Yun Feng 7/5/15
'67 Gerald D. Luzum 1/31/16
'67 C. William Kauffman 5/25/16
'68 J. Dick Pensyl 10/2/15
'68 Dae Y. Cha 5/5/16
'69 David M. Ericson 4/13/16

1970s

'70 David J. Cotcher 3/28/16
'70 Gerald D. Knight 5/12/16
'71 James J. Meagher 11/24/15
'71 David J. Overway 4/23/16
'72 Robert F. Lapinski 8/29/15
'73 Michael K. Brown 2/7/16
'75 Ronald Thompson 8/17/15
'75 Thomas E. Davis 11/22/15
'76 Jack L. Warren 3/23/16
'76 Thomas C. Esper 5/8/16
'77 Dale H. Youngpeter 12/5/15
'77 John R. Young 2/16/16
'78 Edward W. Walsh 2/4/16
'79 Thomas L. Wiese 1/28/16

1980s

'80 Gregory A. Dorr 1/9/16
'80 Richard D. Woltil 4/24/16
'81 Bridget M. Wu 1/3/16
'81 Abraham Shenker 3/27/16
'81 Roger E. Lady 7/21/16
'82 Nicholas G. Caruso 5/29/16
'83 Paul D. Garrett 7/12/15
'83 Ruth A. Brasie 10/15/15
'86 Robert K. McCarren 4/10/16
'87 Richard M. Thomas 1/31/16

1990s

'90 Donna J. Thomason 3/13/16
'90 Michael J. Tolinski 6/14/16
'95 Aveek Guha 3/27/16

2000s

'04 Chuck T. Hui 11/13/15

2010s

'13 Sreyas P. Antony 5/15/16

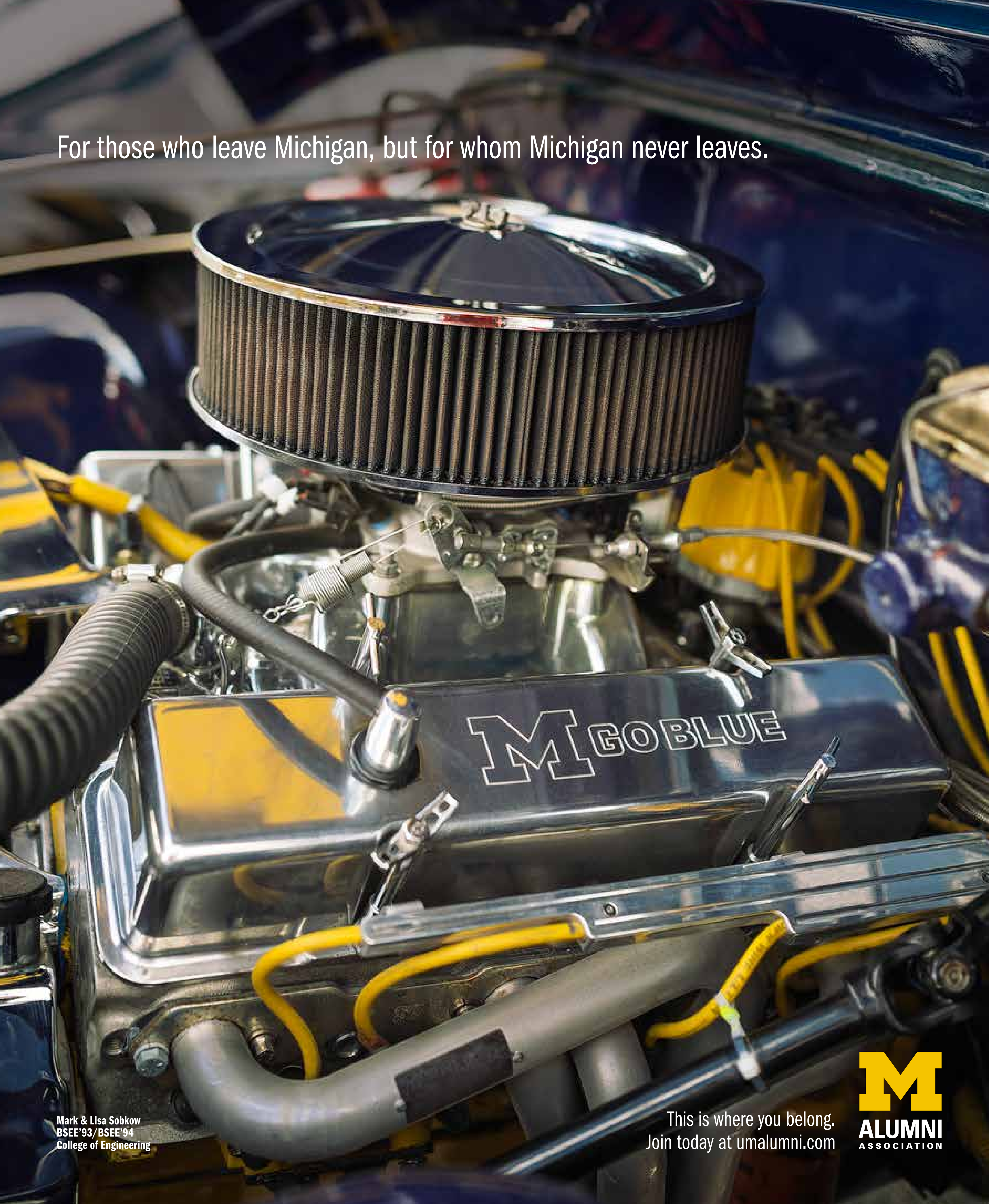

PHOTO: Joseph Xu

NAME THAT CHIP

The U-M Micro/Nano/Molecular Biotechnology Lab produces microfluidic chips that mimic the functions of human organs. They provide a safer, faster, less expensive way to test medications and medical treatments. We think they look pretty cool, too.

Can you guess which organ the chip in this photo replicates?

A. Heart
B. Kidney
C. Liver
D. Spleen

MYSTERY PIC

Can you guess where on North Campus this photo was taken?

PHOTO: Joseph Xu

ANSWERS:

NAME THAT CHIP: *Kidney – Biomedical Engineering professor Shuichi Takayama and his team used this chip to study how a common antibiotic affects kidney cells. It could lead to more precise dosing of drugs in intensive care units, where a significant number of patients experience serious kidney injury from medications.*

To learn more about how the chip works, scan this page with the Decoder in the One Cool Thing app.

MYSTERY PIC: *It's a rare look inside the Ann and Robert H. Lurie Tower, which was specially lit for a Halloween event that took place last year. Completed in 1996, the tower sports a grand carillon of 60 bells that can be played by an operator inside. The bells are made of a bronze alloy containing 80 percent copper and 20 percent tin – a recipe that metallurgists have used for thousands of years to cast bells that sound just right and can last for centuries.*

A VERY, VERY (VERY) SMALL BREAK

That's the kind of break a nano-researcher gets. Sitting just outside the Lurie Nanofabrication Facility (LNF), this researcher uses that time to check email on an iPad. The LNF is a dust-free environment, keeping nanoscale microchips and experiments clean. While some equipment (like cameras and smartphones) can be wiped down and brought inside, this researcher apparently wanted to stay in the prep area and take advantage of the super comfy bench.

PHOTO: Joseph Xu

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