COLLEGE OF ENGINEERING | UNIVERSITY OF WISCONSIN-MADISON

PERSPECTIVE

2018

MAKERSPACE DEBUTS | ROBOTIC CONTROL | STOPPING SUPERBUGS

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College of Engineering
UNIVERSITY OF WISCONSIN–MADISON

PERSPECTIVE MAGAZINE

ENGINEERING EXTERNAL RELATIONS

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GREETINGS ALUMNI AND FRIENDS!

We often describe UW-Madison as a "research powerhouse," and that's a distinction of which we can be very proud. In fact, of nearly 900 institutions included in results of a recent Higher Education Research and Development Survey, the university ranks 6th, with nearly $1.16 billion in annual research expenditures.

In fact, the university's research enterprise is a strong economic engine; for example, research at UW-Madison has yielded more than 300 start-up companies, which support some 25,000 jobs and contribute approximately $2.3 billion to the Wisconsin economy alone. Additionally, UW-Madison is 6th worldwide (and No. 1 in the Big Ten) in U.S. patents issued to universities, and citizens and organizations worldwide benefit from our groundbreaking advances and new knowledge. This is the Wisconsin Idea.

The College of Engineering is a major contributor in the long and important tradition of research excellence. Certainly, the pages of this magazine are filled with news about the research achievements of our engineering faculty, staff, students and alumni.

This strong emphasis on research also is a critical component of our educational mission. Among the benefits to our students, an international reputation for research leadership:

- Enhances our ability to recruit, retain and train the world's best undergraduate and graduate students, whose diversity, curiosity and unique perspectives are a hallmark of our campus culture.
- Enables us to recruit and retain the most innovative faculty who are on the leading edge of their fields. Through their courses, as advisors and mentors, and through experiences in their laboratories, they convey the latest knowledge and their own expertise to our students.
- Allows us to extend research experiences to undergraduates and graduate students alike. These hands-on opportunities augment our students' classroom education and give them access to world-class laboratory facilities and instrumentation. As a result, our students develop as thoughtful, tenacious researchers who can and do make important discoveries and contributions to science.
- Attracts top employers to recruit, with confidence, students who are exceptionally well prepared to make immediate and meaningful contributions in their companies through internships, co-operative work, and permanent positions.
- Opens doors to connections in government, academia and industry around the world, providing our students valuable resources for the next steps in their educational or professional careers.

College of Engineering faculty, staff, students and alumni are known and sought worldwide for their excellence in research, and I am proud to say their work contributes to a healthier, safer and more prosperous society—perhaps the most important research benefit of all.

In this issue of *Perspective*, we've highlighted only a small fraction of our recent research advances. To learn more about what our college—your college—is doing, visit **www.engr.wisc.edu/news/**.

Thank you and **ON, WISCONSIN!**

Ian M. Robertson

Dean Ian Robertson
UW-Madison College of Engineering

UW-MADISON IS A

Research Powerhouse

#6 Ranked #6 out of 900 in Higher Education Research and Development Survey

$1.16B Nearly $1.16 billion in annual research expenditures

300 Research has yielded more than 300 start-up companies

$2.3B Start-ups contributed approximately $2.3 billion to the Wisconsin economy

#1 #1 in the Big Ten, and 6th worldwide, in the number of U.S. patents issued to universities

A BIG STEP FOR GREEN FLOORING

With multiple dielectric layers, the flooring generated an electrostatic charge when subjected to footsteps. The floor panels powered the green LEDs. An example of the voltage and energy generated by each panel is shown below.

As tens of thousands of visitors each day walked across a new section of flooring in UW-Madison's Union South in fall 2017, they participated in what could very well represent an affordable leap into the future of renewable energy production.

Xudong Wang

A research team led by Materials Science and Engineering Professor Xudong Wang, in collaboration with the Grainger Institute for Engineering, installed a high-tech flooring prototype that looks like wood flooring, but harvests the energy of footsteps and converts it into electricity.

"This is the first on-site demonstration of our technology," Wang says. "It shows an exciting path leading materials science technology from the lab toward a real product. It's also an intriguing technology for energy savings, and is beneficial to our environment."

The power-generating floor includes an additional green credential in that its functional component is mostly made from recycled wood pulp—an abundant waste material that's already a common component of flooring.

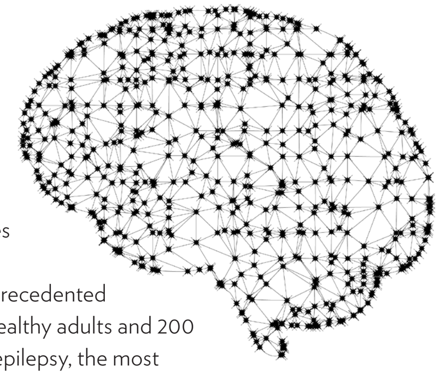
The researchers chemically treat the pulp, which produces a large number of electrostatic charges when it comes into contact with electrodes embedded in the flooring. Embedded wires transmit those charges and can power lights or charge batteries.

Initial testing in Wang's lab shows that the technology works for millions of cycles. "We haven't converted those numbers into years of life for a floor yet, but I think with appropriate design, the technology can outlast the floor itself," he says.

Read more: www.engr.wisc.edu/one-step-closer-market-renewable-energy-flooring-makes-debut-union-south/

Photo: Adrienne Nienow

UNDERSTANDING EPILEPSY



Beth Meyerand

Francis Collins, the director of the National Institutes of Health, has called the human connectome "the symphony in our brain," played by electric circuit connections between its distinct functional regions.

Neurologic diseases can distort that intricate symphony—yet researchers still have a poor understanding of how that happens, prompting Collins to launch the NIH Human Connectome Project in 2009. Its first goal was to map normal connections, or communication patterns, among the nerve cells in different areas of the brain.

In the latest round of funding, NIH now wants researchers to compare those normal patterns to malfunctioning connections caused by different brain diseases. Biomedical Engineering Professor Elizabeth Meyerand is co-leading one of those efforts.

She and her collaborators already have made important advances in understanding how changes in the brain's white matter contribute to epilepsy.

Now, she and colleagues are using MRI and other techniques to map—in unprecedented detail—the brains of 200 healthy adults and 200 adults with temporal lobe epilepsy, the most common form of the disease that affects at least 50 percent of all patients.

Meyerand and her collaborators are especially motivated by the plight of almost 900,000 American epilepsy patients who don't respond to anticonvulsant medications. "Since the existing treatments don't work for a large percentage of patients, we clearly don't understand the disease well enough yet," says Meyerand. "That's why this research is so important."

Read more: www.engr.wisc.edu/studying-human-connectome-increase-understanding-epilepsy/

FOR TRANSFORMING HEALTHCARE, WIHSE IS THE RIGHT PRESCRIPTION

Photo: Stephanie Precourt

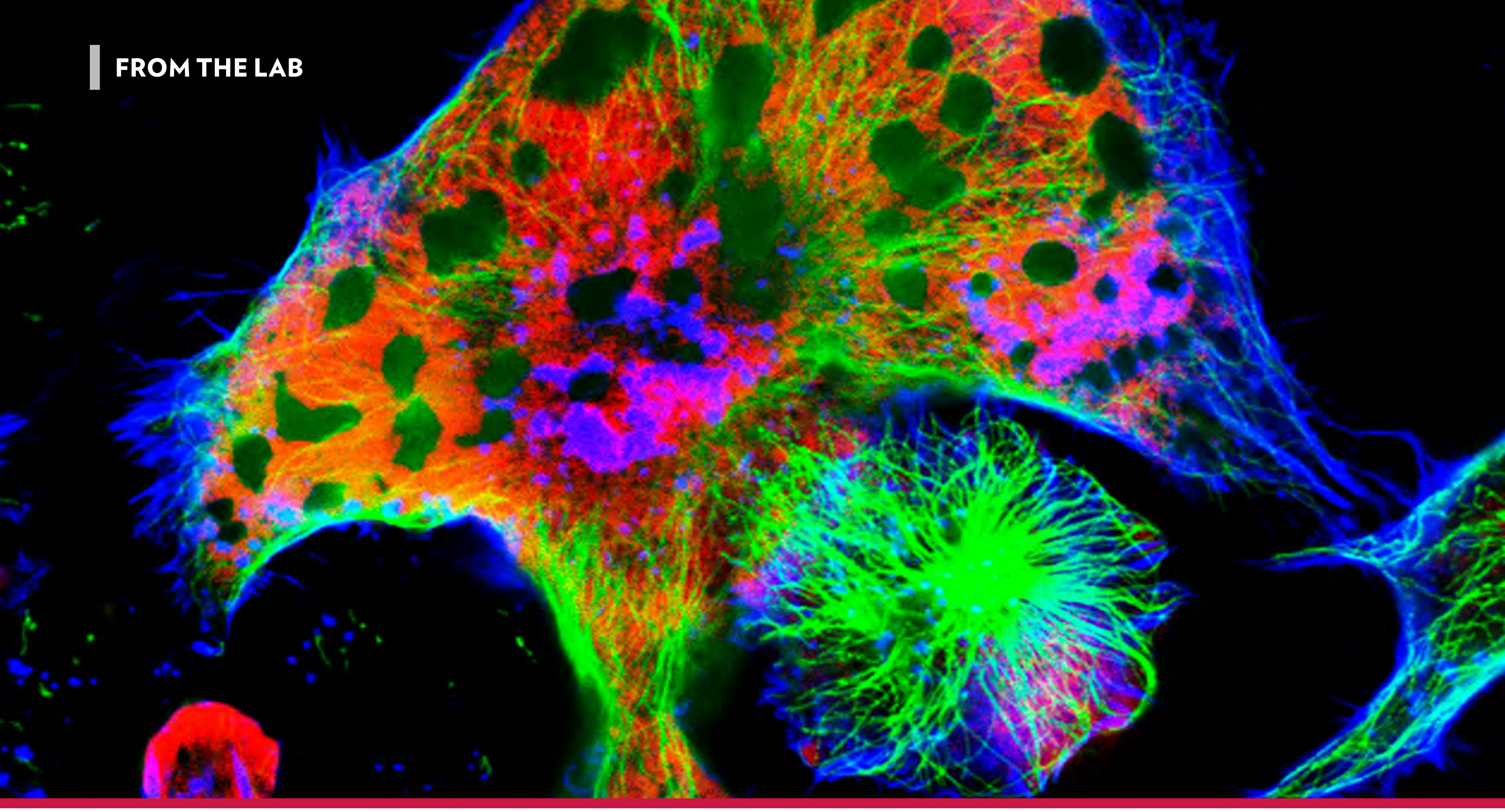
Pascale Carayon hopes the new Wisconsin Institute for Healthcare Systems Engineering (WIHSE) at UW-Madison will become Wisconsin's next key player in transforming the way healthcare is delivered in the United States.

"There aren't many campuses in the country that have strength in engineering, medicine, nursing and pharmacy," says Carayon, the Procter & Gamble Bascom Professor in Total Quality in industrial and systems engineering who also leads smart and connected healthcare research for the college's Grainger Institute for Engineering. "We have been building transdisciplinary collaborations among these four entities for years. Taking advantage of this unique crossroads, we hope to become a national model for an institute of this kind."

In realizing their vision of transforming healthcare through engineering, institute researchers and industry partners hope to reduce preventable medical errors, which are the third-leading cause of death after heart attacks and cancer; increase the number of Americans who receive their recommended care; control the growth of healthcare costs, and reduce physician burnout.

Central to these overarching goals is the idea of modeling what health systems engineers call the patient journey. "We don't just want to understand what happens when patients physically interact with their healthcare providers," Carayon explains. "We want to build a system that supports ongoing communication between these partners in care, especially when they are distributed over space and time and affiliated with several distinct organizations."

Read more: www.engr.wisc.edu/new-academic-industry-effort-uw-madison-aims-improve-healthcare-engineering/



MAKING CELLS FOR MODERN MEDICINE

UW-Madison is among a consortium of universities that received nearly $20 million from the National Science Foundation (NSF) to develop transformative tools and technologies that enable them to produce low-cost, high-quality living therapeutic cells. Such cells could be used in a broad range of life-saving medical therapies now emerging from research laboratories.

Working closely with industry and clinical partners, researchers in the new NSF Engineering Research Center for Cell Manufacturing Technologies could help revolutionize the treatment of cancer, heart disease, autoimmune diseases and other disorders.

UW-Madison researchers are focusing on two disease applications: induced pluripotent stem cells for making heart muscle and engineered T cells to combat cancer. "Engineering the patient's own T cells to recognize and kill tumor cells is one of the new frontiers in cancer research," says Sean Palecek, the Milton J. and A. Maude Shoemaker Professor in chemical and biological engineering who is the center's associate director for research. "But more work is needed to prevent a massive immune response in the patients who receive these modified T cells, and to learn how this type of therapy may eventually be applied to solid tumors as well."

Photo: Stephanie Precourt

Sean Palecek and UW-Madison researchers will focus on two disease applications: induced pluripotent stem cells for making heart muscle and engineered T cells to combat cancer.

Read more: www.engr.wisc.edu/uw-madison-major-partner-20-million-research-center-expand-use-therapies-based-living-cells/

20+ YEARS OF FUNDING FOR FUNDAMENTAL MATERIALS RESEARCH

Chemical engineering PhD student Yingxin Guan conducts research with a plasma focused ion beam microscope (pictured in background). The microscope is used for high-speed nanomachining to create test samples for transmission electron microscopy and other experiments.

With $15.6 million, the National Science Foundation has renewed our Materials Research Science and Engineering Center. Housed in the college, MRSEC includes 30 affiliated faculty from nine departments across the university.

The funding marks more than two decades of NSF support for UW-Madison researchers' quest to investigate fundamental, large-scale and complex questions in materials science.

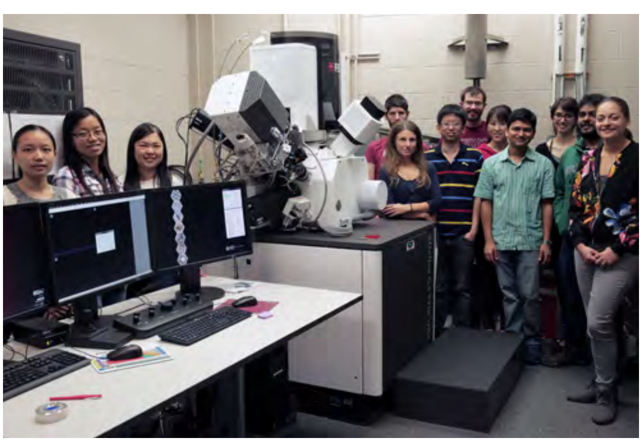
This long-term commitment has produced pioneering breakthroughs—for example, liquid crystals for sensing, with applications in wearable technologies that detect airborne toxic gases. MRSEC researchers also have characterized the extremely efficient energy transfer capacity of carbon nanotubes; that property makes them a promising candidate for next-generation solar energy harvesting.

And MRSEC faculty are pursuing breakthroughs in other materials.

One of those advances could come by way of glassy materials, which have a "disordered" atomic structure. Better understanding of these materials could lead to new glasses that might extend the life of machine tools, enable advances in quantum computing, or lead to better cell phone displays, for example.

Another major area of MRSEC research seeks to fabricate films out of complex oxides, which also has the potential to impact quantum information technologies, including quantum computing.

MRSEC also funds internationally recognized educational and outreach programs that support up-and-coming researchers and schoolchildren alike.



MRSEC's broad impact on campus also is tangible, says director Nicholas Abbott, the John T. and Magdalen L. Sobota Professor and Hilldale Professor of chemical and biological engineering. He notes that millions of dollars' worth of scientific equipment has been purchased through MRSEC funds, including equipment that is available for use by industry and researchers both on and off the UW-Madison campus.

MRSEC also runs the Advanced Materials Industrial Consortium, a group of companies that, together with MRSEC faculty and staff, provides invaluable professional development opportunities for UW-Madison students and researchers. "There are many facets to MRSEC," Abbott says.

And all of the facets add up to an exceptional home for the exchange of ideas and knowledge across disciplines, ultimately enhancing the educational mission of the university.

Read more: www.engr.wisc.edu/major-nsf-sponsored-materials-research-collaboration-receives-15-6m-grant/

Graduate students from the MRSEC interdisciplinary research groups are pictured in the Materials Science Center with the plasma focused ion beam microscope. This particular microscope was the first next-generation instrument of this type installed in the United States.

Photos: Renee Meiller

FOR NUCLEAR FUEL, WE'VE GOT IT COVERED

Photo: Stephanie Precourt

In the cold spray laboratory, undergraduate student Jorie Walters positions a zirconium alloy tube in the holder for the powder cold spray deposition process, while PhD student Ben Maier looks on.

Kumar Sridharan, a distinguished research professor of engineering physics and materials science and engineering, aims to increase the tolerance of the fuel rods used in today's nuclear power reactors, particularly in the event of a "beyond-design-basis" accident. He is collaborating with researchers at Westinghouse Electric Company.

They are drawing on Sridharan's expertise in a process called powder cold spray deposition—essentially, shooting powdered particles of a material at a surface at supersonic velocities so that the particles flatten out and coat the surface.

They're using this simple, fast and cost-effective process to apply an oxidation-resistant metallic coating to zirconium alloy fuel rods.

When zirconium heats up, it oxidizes exothermically, and that reaction produces a lot of heat, as well as hydrogen gas. The team's protective metallic coating would slow oxidization and hydrogen generation—potentially preventing a nuclear emergency or significantly mitigating its consequences by providing additional operating time at high temperature, as well as time for reactor operators to react.

At locations around the world, they're testing the coated zirconium alloy sections in a prototypical light water reactor environment, in steam at temperatures exceeding 1,300 degrees Celsius, and under neutron irradiation.

Read more: www.engr.wisc.edu/uw-madison-nuclear-fuel-coating-helping-revolutionize-nuclear-fuel/

OPTOELECTRONICS ORIGAMI

CONVEX

CONCAVE

MODEL

These days, we increasingly rely on our cell phone cameras to capture virtually every aspect of our lives. Far too often, however, we end up with photos that are a sub-par reproduction of reality.

And while operator error sometimes comes into play, most likely, the camera's digital image sensor is the real culprit. A flat silicon surface, it just can't process images captured by a curved camera lens as well as the similarly curved image sensors—otherwise known as the retinas—in human eyes.

Now flexible optoelectronics pioneer Zhenqiang (Jack) Ma, the Lynn H. Matthias and Vilas Distinguished Achievement Professor of electrical and computer engineering, has devised a method for making curved digital image sensors in shapes that mimic an insect's compound eye (convex) and a mammal's "pinhole" eye (concave). It's a breakthrough that could, for example, lead to cameras with beyond-the-state-of-the-art features such as infinite depth of field, wider view angle, low aberrations, and vastly increased pixel density.

Ma's technique was inspired by traditional Japanese origami, or the art of paper-folding: He and his students formed pixels by mapping repeating geometric shapes—somewhat like a soccer ball—onto a thin, flat flexible sheet of silicon called a nanomembrane, which sits on a flexible substrate. Then, they used a laser to cut away some of those pixels so that the remaining silicon formed perfect seams, with no gaps, when they placed it atop a dome shape (for a the convex detector) or into a bowl shape (for a concave detector).

Read more: www.engr.wisc.edu/optoelectronics-origami-curved-image-sensor/

ANSWERING BIG QUESTIONS ABOUT DATA

Data science has transformed fields from biology to astronomy, and social networks to politics, influencing most aspects of modern life. Now to transform data science, a multidisciplinary team of researchers at UW-Madison aims to return to the fundamentals.

With a $1.5 million grant from the National Science Foundation, they have created the Institute for Foundations of Data Science, which is housed in the multidisciplinary Wisconsin Institute for Discovery and includes several faculty in electrical and computer engineering (ECE).

Researchers in the institute will play a key role in the future of data science, developing fundamental techniques for handling increasingly massive data sets in shorter times.

The institute has three research themes. ECE faculty members Robert Nowak, Dimitris Papailiopoulos and Nigel Boston are leading projects under the algebra and optimization in data science theme. ECE Associate Professor Rebecca Willett and Statistics Professor Michael Newton are leading projects in the graphs and networks in data science theme, while ECE Assistant Professor Po-Ling Loh and Computer Sciences Professor Jerry Zhu are leading projects in the data acquisition theory and methods theme.

Researchers in the institute also plan to enrich graduate programs in data science and foster outreach to industrial partners with interests in fundamental data science research.

Read more: **www.engr.wisc.edu/interdisciplinary-faculty-build-data-science-future-new-institute/**

AID FOR OPIOID ADDICTS

In the United States, there are 24 million people addicted to alcohol, illicit drugs or opioid painkillers, yet only 4 million are in treatment. As a country, there's a growing need to close that gap, and with $3.8 million from the U.S. Department of Health and Human Services, our industrial and systems engineers aim to improve access to and the quality of addiction treatment recovery services in the Midwest.

Read more about this initiative: **www.engr.wisc.edu/uw-madison-joins-national-network-combat-opioid-epidemic-substance-use-disorders/**

FOCUS ON A FEW NEW FACULTY

Eric Severson: Finding ways to reduce energy consumption

Given that 45 percent of the world's electric energy is consumed by electric motor systems, the need to replace inefficient, outdated motor systems with new, highly efficient technology is a challenge Eric Severson is excited to address. Severson joined the Department of Electrical and Computer Engineering as an assistant professor in fall 2017. He also is a fellow of the Grainger Institute for Engineering.

Read more about Eric's work: www.engr.wisc.edu/focus-new-faculty-eric-severson-finding-ways-reduce-energy-consumption/

Kassem Fawaz: Bringing security and privacy protection to the masses

From smartphones to fitness trackers to pacemakers and more, it's pretty difficult to keep our devices secure and our personal information private. That's where Kassem Fawaz steps in. Fawaz, who joined the Department of Electrical and Computer Engineering as an assistant professor in fall 2017, aims to develop security and privacy systems that help people protect themselves.

Read more about Kassem's work: www.engr.wisc.edu/focus-new-faculty-kassem-fawaz-bringing-security-privacy-protection-masses/

Ramathasan Thevamaran: Structuring materials to function how we need them to

Ramathasan Thevamaran, who joined the Department of Engineering Physics in fall 2017, manipulates materials to give them specific functionality. Down the road, for example, that could mean submarine surfaces that make these vessels undetectable, or energy-absorbing football helmet foam that protects athletes from brain injuries.

Read more about Ramathasan's work: www.engr.wisc.edu/focus-new-faculty-ramathasan-thevamaran-structuring-materials-function-need/

Greeshma Gadikota: Using green chemistry to close elemental loops

A chemical engineer by training, Greeshma Gadikota studies the intricate chemical properties of the materials we use to produce energy and consumer goods. Her goal: close elemental loops—for example, the carbon loop—with more sustainable chemical reactions. Gadikota joined the Department of Civil and Environmental Engineering as an assistant professor in fall 2017. She also is a fellow of the Grainger Institute for Engineering.

Read more about Greeshma's work: www.engr.wisc.edu/focus-new-faculty-greeshma-gadikota-using-green-chemistry-close-elemental-loops/

RENOWNED ENGINEER ED LIGHTFOOT PASSES AWAY

Edwin Lightfoot, Hilldale professor emeritus of chemical engineering, died Monday, Oct. 2, 2017, at age 92.

Lightfoot was a brilliant researcher known for his ability to clearly convey complex topics in the classroom and instill a love of learning—and of chemical engineering—in his students.

Following World War II, as the field of chemical engineering matured and challenges became more complex, Lightfoot and colleagues R. Byron (Bob) Bird and Warren Stewart (who passed away at age 81 in 2006) recognized a growing need to provide students unifying principles in a variety of transport phenomena. That came in the form of the seminal textbook, *Transport Phenomena*.

Lightfoot was a brilliant researcher known for his ability to clearly convey complex topics in the classroom and instill a love of learning—and of chemical engineering—in his students.

A few of Ed Lightfoot's graduate students gather for a photo with him in honor of his 90th birthday.

Lightfoot himself conducted groundbreaking and interdisciplinary research in biochemical engineering, focusing specifically on separation processes and controlling the dynamics of biological systems—interests intended to advance biotechnology.

Among his numerous honors are distinguished honorary doctorates from the Technical University of Norway and the Technical University of Denmark. He was elected a fellow of the American Academy of Arts and Sciences in 1992 and also in 1992 was a founding fellow of the American Institute of Medical and Biological Engineering. He was elected to the National Academy of Engineering in 1979 and, with his election to the National Academy of Sciences in 1995, became one of only three faculty members in the College of Engineering to hold that distinction. In 2004, he also received the National Medal of Science from U.S. President George W. Bush for his leadership in transport phenomena.

Ed Lightfoot (left) with Victor P. Goldbach, November, 1968. At the time, Goldbach was an assistant of Dr. and Professor Arvin Weinstein in the School of Medicine. Lightfoot was collaborating with Weinstein on a project that led to the establishment of the UW hemodialysis center when this photo was taken.

Read more about Ed: **www.engr.wisc.edu/renowned-biochemical-engineer-edwin-n-lightfoot-passes-away/**

Photo: Stephanie Precourt

Making ideas possible

A makerspace is a place where creativity knows no bounds.

And the Grainger Engineering Design Innovation Laboratory—part of the new engineering makerspace—already aims to be a place where limits don't exist.

Located in our Wendt building, the makerspace opened in September 2017. It's available to all College of Engineering students, faculty and staff, as well as their collaborators from other parts of campus.

The 12,000-square-foot space is a maker's dream; it houses 3D printers, laser cutters, machine tools, virtual and augmented reality hardware, microscopes, soldering irons, bicycle tools and many more instruments and gadgets to assist engineering students in bringing their ideas to life.

The facility's core purpose is to be a resource for engineering students as they work on class projects or develop their own ideas. For example, the seniors and graduate students in *Design of Orthopedic Implants*, Mechanical Engineering Associate Professor Heidi Ploeg's course, used the makerspace's enormous interactive touchscreen and virtual reality headset to study bone joint anatomy. They used the technology to study computed tomography (CT) scan data from the National Library of Medicine, which provides the basis for the total joint replacements they'll develop using computer modeling. The 10 teams of four students each then used the visualization tools to examine their implant models before they finally printed them, also at the makerspace, with a 3D printer.

Within 75 minutes of providing students with the CT scan data for the human joints they would be tasked with replacing, Ploeg says each of the 10 teams had a computer model ready to share. "I think it helps that we were in this cool room where we could interact with the models with shared screens, including this huge touchscreen," Ploeg says.

The ability to 3D print their models was the cherry on top of an already fun learning experience, Ploeg adds. "Even when you're able to see and interact with a model on a screen, it's a totally different experience to be able to interact with the model physically," Ploeg says. "You see, and feel, more details and can understand it better. It's a whole different interaction."

All possibilities really are as limitless as the ideas that users bring to the space.

Photos: Renee Meiller


NATIONAL AIR AND SPACE MUSEUM
SMITHSONIAN INSTITUTION

Photos: Renee Meiller

Designing human-centered robots is a study in control

By Will Cushman

In that far, far away galaxy where rebel Jedi once fought the dark forces of a galactic empire, robots played an integral role in daily life. From Roomba-like floor machines roaming the Death Star's corridors to utilitarian spacecraft mechanics like R2-D2 and BB-8 to humanlike androids the likes of C-3PO and the lesser known surgical android 2-1B, the robots of Star Wars relied on robust artificial intelligence and varying degrees of dexterity to perform their tasks.

They're also, obviously, the product of science fiction.

But here, planted firmly in the reality of planet Earth, artificial intelligence is rapidly transforming our digital lives. Certainly robots are quickly becoming more intelligent, thanks to supercomputing and machine learning—but, apart from the machines that perform single or highly repetitive tasks, robots as they've largely been imagined in science fiction are still mostly absent in our physical lives. Indeed, robots' ascendance from the floors of our factories and homes to our surgery theaters and other settings that require higher and more complex functions so far has been halting.

That's largely because engineers must overcome enormous challenges to control the precise physical movements of machines.

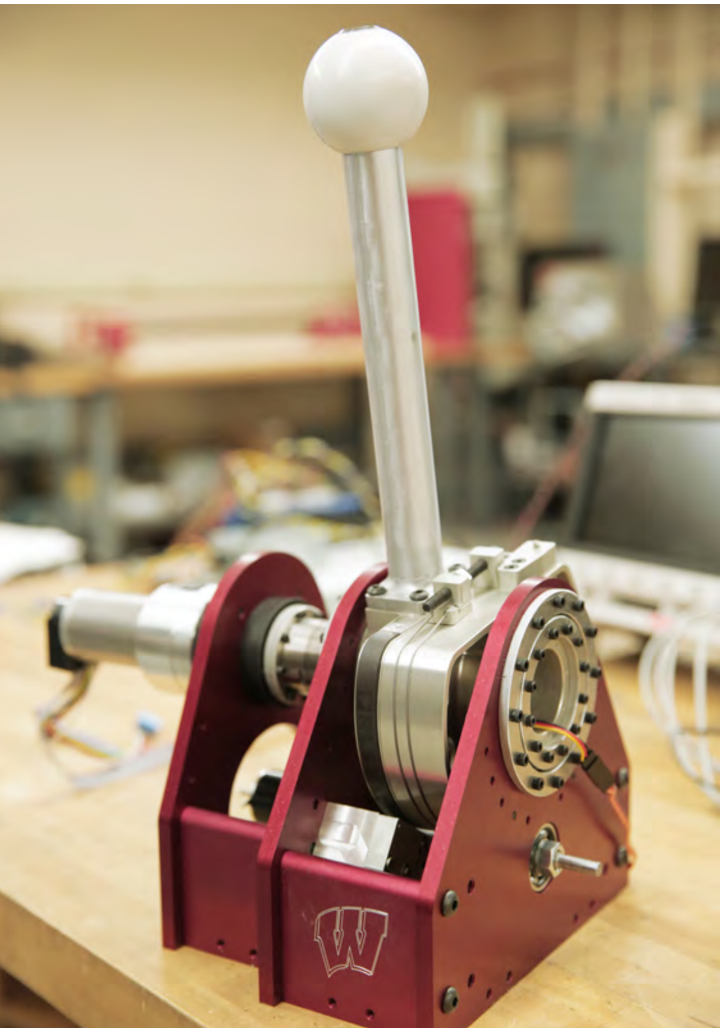
Developing human-centered robots—machines whose physical interactions with humans are every bit as precise and complex as their intellectual interactions—is especially daunting, and mechanical engineers Michael Zinn and Peter Adamczyk are among engineers all over the world who are working on the task. Their research largely focuses on robotics and ranges from fundamental control problems to robotic rehabilitation and other healthcare applications.

Making the virtual more realistic

Zinn, an associate professor of mechanical engineering, is in the midst of exploring several lines of human-centered robotics research. Zinn's research spans a range of fundamental inquiries and development of specific devices; for example, he's helped design robotic catheters and robotic motor skills assessment systems for autistic children. Zinn heads the UW-Madison REACH (Robotics Engineering, Applied Controls and Haptics) Lab, where he spends a lot of time devising and testing control systems that allow humans to interact ever more intimately with robots and with virtual-robotic environments.

"Fundamentally, I'm kind of a nerd," says Zinn, as he explains the immense challenge of designing a robotic system that can move with the precision, speed, dexterity and care that will be required if robots are to ever make the leap from single-skilled automatons relegated to their workstations to something more akin to a corporeal Siri. "It's fun," he adds. "The stuff I do is scientifically rigorous, but at the same time we're building these electromechanical things that do what you want them to do. It's empowering."

One area that is receiving more and more attention in robotics-related research is the subfield of haptics, Zinn says. Within the context of robotics and systems control, haptics deals with interfaces and devices that are meant to allow people to interact physically with a virtual world. At its most basic level, think of a video game controller that vibrates as a way of representing intense physical movements within a game. Zinn is currently working on a haptics problem on behalf of a research firm that sells reality retail products. The ultimate goal is to design a control system that allows for much more varied and nuanced physical interactions between humans and a virtual environment. It's an exceedingly tough nut to crack, and Zinn is working on fundamental problems.



Zinn is collaborating with staff at a virtual reality company on refining the haptics, or touch interactions, that can make virtual reality experiences more "real."

"There are current devices that are supposed to accomplish this task, including gloves, devices that are essentially a 3D joystick and devices that look like little robots," says Zinn. "All of them work okay to bad."

The challenge is designing a device that can create plausible sensory effects at the extremes—like a hard tabletop or a soft robe. Right now, he's working on a line of hybrid actuation devices, which are a combination of motors and passive systems that essentially work as brakes.

"The advantage of a brake in the system is: Imagine that I have a device, and I'm about to push on a surface and then I just lock the device with brakes. It's going to be as stiff as that device structure is," Zinn explains.

Brakes such as these could be useful for creating relatively stiff sensations for users. "I can achieve that stiffness with no power," Zinn says. "But the brake can't push back because it's passive and its only function is to take energy out of the system. So, you have to pair it with active devices, and people have tried to do this with very limited success. The result is a very asymmetric system where you can get super high stiffness or nothing."

The virtual reality company approached Zinn after reviewing his PhD research from years ago when Zinn was exploring the design of active devices that could help create some of the more intermediate haptic effects. That design pairs a large motor and a small motor as the active elements—a pairing that Zinn called "macro-mini" in his PhD work. The idea is that each of the motors specializes in different haptic sensations.

Peter Adamczyk in his office in the Mechanical Engineering Building. In the foreground are some of the prosthetic feet he is working on.

"The big motor is good at low frequency stuff, where it can push back really hard but can't respond quickly," Zinn explains. "Meanwhile the small motor's good at responding quickly and can give you a good punch over a short duration. When you pair the two, you can span a larger range in terms of the speed of response."

Zinn's current device looks like joystick with only one degree of freedom. "Eventually you would want it to work in a 3D setting, but we're working on some fundamental controls elements," he says.

The relatively basic design features a knob that pivots above an axis with a series elastic actuator—essentially a fancy spring—attached to one side. The spring connects to a big gear head and then a motor and allows the device to produce a wider spectrum of forces.

"If I didn't have this spring, the device could produce very high forces, but when I want it to produce zero forces it would be terrible," Zinn says.

He's early in the process, but it's these kinds of fundamental problems that get Zinn excited. He also collaborates with researchers in the Department of Computer Science who are working on other fundamental human-robot interaction problems.

Making strides in robotic rehab

Adamczyk, whose office door is about 6 feet from Zinn's, came to UW-Madison as an assistant professor of mechanical engineering in 2015 and has since set up the UW BADGER Lab. BADGER stands for Biomechatronics, Assistive Devices, Gait Engineering and Rehabilitation. As the name suggests, Adamczyk and his students develop mechanical and robotic solutions for people with mobility issues. In particular, Adamczyk has focused on robotic foot prostheses and lower limb rehabilitation. Both of these goals require robotic elements that are able to sense and properly respond to human movements in real time.

The sensing portion is simpler than the physical response portion. For the limb rehabilitation research, Adamczyk uses wearable inertial sensors; they're a combination of an accelerometer, for measuring acceleration, and a gyroscope, for measuring orientation. The sensors are placed on a person's foot and can measure motions in minute detail. The data they collect are useful for informing robotic devices about the range of motion that is normal in a foot, as well as what types of motion are associated with acute injuries or chronic conditions. Adamczyk is leveraging these data for the complex task of building robots with dynamic control systems that are sophisticated enough to not only measure the motion in a person's moving foot or leg, but to also respond to that motion in a way that helps the person move better. Despite, or perhaps because of, the complex nature of this task, Adamczyk relishes the challenge.

“I love the systems development part of robotics,” says Adamczyk. “It’s what I spend my free time dreaming about. I love mechanisms and control, and I love dreaming outside the box about how these systems can be useful to humanity.”

In his latest research, Adamczyk aims to develop a robotic system that is useful to people who need extensive leg rehabilitation. The target is stroke victims who have to completely relearn how to use their legs, but the system could be used for people with a wide range of ailments that require extensive leg rehab, including people with cerebral palsy and musculoskeletal injuries such as knee replacement.

Adamczyk cautions that the project is still young and nebulous, but he’s excited about its potential to fill a gap in robotics.

“People have done a lot of work on similar robotic applications for upper limbs,” Adamczyk says.

In particular, researchers have progressed fairly far in a core area of rehabilitation, where the patient tries to perform specific movements while encountering resistance. Traditionally, this resistance is provided via imprecise mechanical machines or highly trained—and expensive—physical therapists. The idea is that robotic systems could interact with a patient even more precisely than a human therapist and, by doing so, make rehabilitation more effective.

Upper limbs have received this type of research attention, but not so with legs, says Adamczyk, sniffing an opportunity.

“We’ve set out, with the understanding that there’s a research gap there, to design tasks that require some sort of volitional movement and strength on the part of the patient,” he says.

To accomplish this, Adamczyk is designing a rehabilitation robot that looks a lot like a regular motor-controlled exercise bike. But, instead of the person pedaling the bike, the bike pedals the person—and only when the person pushes on it with very specific forces under his or her feet. Adamczyk’s research aims to determine how those forces can best be used to retrain movement. In collaboration with Zinn, he hopes to develop a more advanced system that moves in multiple directions.

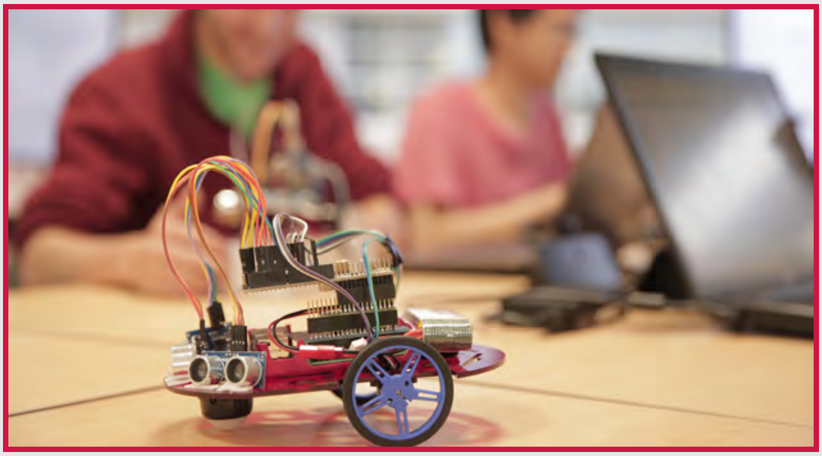
Refining robotics for the future

All of this is easier said than done. Zinn explains that a core issue with human-centered robotics going forward will be developing ways for robots to simulate lifelike movement that is imbued with complexity so subtle that researchers still are having difficulty translating it to the language of engineering and machines.

“A great example of this the task of picking a fresh peach off of a tree,” Zinn explains. “I could explain to you how to do it, and with a little bit of practice you would learn to squeeze it enough to decide if it’s ripe enough to pick, but not squeeze it so hard that you squish it. So, how can I describe that to a robot and make it do the same thing? Certainly, it’s not only a matter of precision. How do I describe what that physical interaction is so I can now, in a training environment for robots, achieve the desired result? We’re just getting started on that.”

‘Machine’ learning

In addition to their robotics research, Zinn, Adamczyk and their colleagues teach courses on robotics and control topics at both the undergraduate and graduate levels. In fall 2017, for example, Adamczyk taught *Introduction to Robotics*, a hands-on class for seniors and graduate students that introduces them to the key concepts and tools underpinning robotic systems in use and development today.



NEW WEAPONS AGAINST OLD ENEMIES

Alexander Fleming discovered penicillin in 1928—and arguably changed the course of history as the drug not only saved thousands of lives during World War II, but also laid the foundation for the antibiotic era that gave us decades of relative protection from previously deadly diseases.

Not even a century later, our excessive use of these miracle antibiotics has turned the tide against us and requires a renewed search for drugs that target the same kinds of bugs we've known for centuries. Now, however, they've become "superbugs," due to the genetic resistance they have developed against our original line of defense.

For the World Health Organization, antibiotic resistance is one of the biggest threats to global health and food security today, and researchers in the College of Engineering are helping to reduce that threat by limiting the spread of superbugs in hospitals and by developing new drugs that are less likely to elicit microbial resistance.

By Silke Schmidt

The researchers found that regular cleaning with sporicidal disinfectants was among the most effective ways of containing the spread of superbugs.

Containing hospital-acquired infections

Industrial and Systems Engineering Professor Oguzhan Alagoz first became interested in infectious diseases in 2009 when physician Nasia Safdar in the UW School of Medicine and Public Health alerted him to the bacterium *Clostridium difficile*, which often infects the colon of patients after they have been admitted to the hospital. It's a growing concern, both for her patients in Madison and for many others around the world.

These diarrhea-causing colon infections can be deadly for the already compromised immune system of patients undergoing cancer chemotherapy or receiving an organ transplant. The emergence of several drug-resistant *C. diff.* strains has contributed to an alarming increase in disease during the past decade, with almost half a million estimated infections and 30,000 deaths in 2011.

For Alagoz, the weapon of choice against *C. diff.* is an agent-based simulation: a mathematical model that mimics its transmission and identifies the best interventions for containing its spread—all while being much less expensive than a clinical trial. The "agents" in the model are hypothetical patients, doctors, nurses and visitors who interact with each other in rooms that may also become contaminated with *C. diff.*

Programmed by MD/PhD student Anna Barker, whose advisors are Alagoz and Safdar, a network of computers simulates the movement of these agents within their environment during the course of a year and reflects the complex reality of an actual hospital much better than traditional epidemiologic models.

The simulations rely on data from previous studies and recent hospital admissions records, such as the length of a patient's stay; the frequency and duration of interactions between patients, healthcare workers and visitors; the probability of *C. diff.* transmission during person-to-person and person-to-environment contact; and the ability of nine different interventions, such as hand washing or room cleaning, to reduce transmission probabilities and limit the spread of *C. diff.*

Armed with a plausible range for these quantities, the model generates millions of possible infection paths and tests the effect of each intervention on these paths.

The results could be a game-changer: The model delivers estimated success rates (and their precision) for one intervention at a time and for any desired combination. "We found that the two most effective interventions were daily room cleaning with a sporicidal disinfectant and the *C. diff.* screening of patients' stool samples when they are first admitted to the hospital," Alagoz says.

Sporicidal disinfectants destroy the dormant and drug-resistant cells, or spores, that *C. diff.* forms to survive periods of nutrient deprivation, while the screening identifies patients who harbor the bacteria, but have not yet developed symptoms that would trigger existing intervention protocols.

Implemented together, these two strategies reduced hospital-onset infection by more than 80 percent in the simulations and were much more effective than visitor hand hygiene and contact precautions.

Alagoz and Safdar have submitted a grant proposal for follow-up work. The two most important next steps, they say, are to compare the model's predictions with actually observed infections and to identify the best sequence of interventions a hospital should implement, given its patient volume and budgetary constraints. "If our proposal is funded and our model can be validated, I believe it could be used in four to five years by any hospital in the country to contain the spread of *C. diff.* infections," Alagoz says.

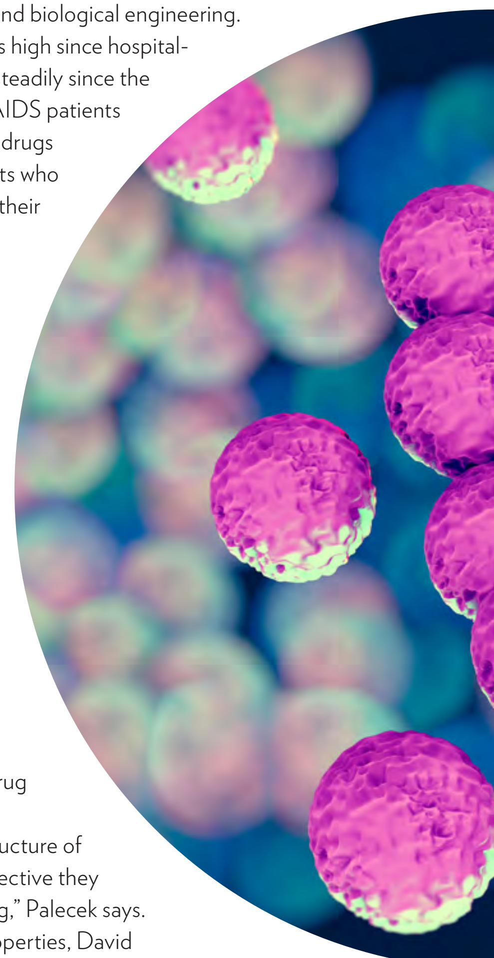
Designing next-generation antifungal drugs

Across the street from Alagoz's office, chemical engineers Sean Palecek and David Lynn have teamed up with Chemistry Professor Samuel Gellman to tackle the superbug problem from a basic science angle.

They are studying antimicrobial peptides, a promising class of pharmaceuticals that could make it more difficult for microbes to become drug-resistant. The researchers are currently focusing on fungi, whose cells are much more similar to our own than to those of bacterial and viral microbes.

Oguzhan Alagoz

"Because of this similarity, it's very challenging to develop selective antifungal drugs that aren't toxic to human cells," says Palecek, the Milton J. and A. Maude Shoemaker Professor in chemical and biological engineering.



Yet, the clinical demand for such drugs is high since hospital-acquired fungal infections have increased steadily since the early 1990s, especially in cancer and HIV/AIDS patients whose immune system is weakened by the drugs they receive and in organ transplant patients who are given immunosuppressants to prevent their bodies from rejecting their new organs.

Palecek's strategy is to engineer synthetic antimicrobial peptides. He aims to mimic the desirable properties of their naturally occurring counterparts while improving upon the undesirable ones, such as their chemical instability. His lab has used peptides extracted from the skin of Australian bell frogs as a starting point.

The frog's peptide and Palecek's synthetic version both target cell membranes. However, the synthetic peptide is designed to resist degradation by cellular enzymes and to disrupt the external membranes of fungal, but not human cells. Since the peptide interacts with multiple components on the fungal cell pores, the fungi are less likely to develop drug resistance.

Sean Palecek

"The better we can mimic the folded structure of native antimicrobial peptides, the more effective they seem to be, which is an encouraging finding," Palecek says.

While he tweaks the drug's chemical properties, David Lynn, the Duane H. and Dorothy M. Bluemke Professor and Vilas Distinguished Achievement Professor in chemical and biological engineering, focuses on delivering it only to the cells it is supposed to attack.

These cells typically gather on the surface of catheters and other medical devices. For example, *Candida albicans*, the most common fungal pathogen in humans, forms a biofilm on such devices that often gives rise to drug-resistant cells.

"Since the synthetic peptide is toxic, we can't just shoot it into a person's bloodstream," Palecek explains. "But if we coat a catheter with the special layer of chemicals that Dave's lab has developed before we put it in, a slow and sustained drug release at that specific site will kill the fungal calls while only a small amount will reach the rest of the body."

Alagoz relies on Safdar's clinical intuition to decide which variables to include in his agent-based model. Similarly, Palecek and Lynn collaborate with infectious disease physician David Andes in the UW School of Medicine and Public Health to evaluate their strategies in clinically relevant settings.

In 2016, Palecek, Lynn and Andes showed that coating a catheter with the slow-release antimicrobial peptide reduced the severity of *C. albicans* infection in a rat model. Andes says it is difficult to put an exact timeline on moving the research findings from the lab to the clinic, but believes that preclinical efficacy and safety studies will begin in the next few years.

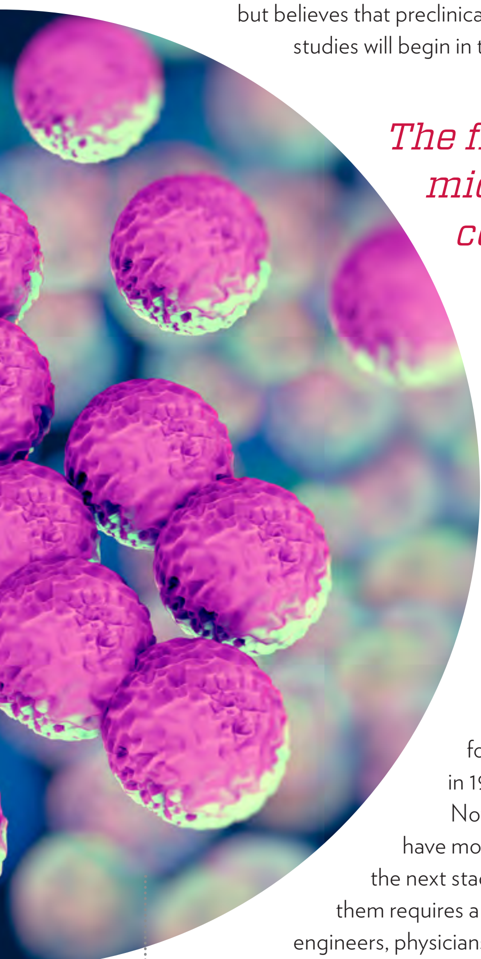
Collaborators David Lynn, the Duane H. and Dorothy M. Bluemke professor and Vilas Distinguished Achievement professor, and Helen Blackwell, a professor of chemistry at UW-Madison, approach the control of bacterial infections not by blasting them with toxic antibiotics, but instead by inhibiting the ability of bacteria to become infectious in the first place. *Photo: Stephanie Precourt.*

The fight against microbes continues

Almost 100 years ago, Alexander Fleming's discovery of penicillin was serendipitous and it took 12 more years until Howard Florey and Ernst Chain proved its power to treat infectious diseases in 1940. The three scientists shared the Nobel Prize for these achievements in 1945.

Now that the superbugs have mounted their defense, the next stage of our battle against them requires a concerted effort on a global scale that unites engineers, physicians and many other researchers under the World Health Organization's global action plan on antimicrobial resistance.

The WHO's goal of continuing to treat and prevent infectious diseases with drugs that are used responsibly and available to all who need them is a tall order, but whether it's reached by systematic pursuit, serendipity or a combination of both, few stones will be left unturned along the way.



Superbugs like MRSA, as seen under a microscope, are strains of bacteria that are resistant to several types of antibiotics. Each year these bacteria infect more than two million people nationwide and kill at least 23,000, according to the U.S. Centers for Disease Control and Prevention.

Photos: Renee Meiller

COLLEGE WELCOMES 1,100+ NEW STUDENTS

On Sept. 5, 2017, the College of Engineering welcomed some-1,100 new students with a daylong event on Engineering Mall. Designed to help new students meet their peers and become part of the Wisconsin engineering community, the event included lots of social time, a walk down Dayton Street to the chancellor's convocation at the Kohl Center, lunch on Engineering Mall, and a fun, timed team-building activity.

INNOVATING FOR ELON

When the SpaceX-sponsored Hyperloop Pod Competition II weekend, Aug. 25-27, 2017, was all said and done, our Badgerloop team was among the top competitors. While there was only time for the top-three teams' pods to run in the Hyperloop vacuum tube, the Badgerloop team—which consists primarily of undergrads—built a functioning pod that passed all tests and earned the team one of the competition's coveted innovation awards. Badgerloop is the only team to receive innovation awards in back-to-back Hyperloop competitions.

Read more about the students' achievements: www.engr.wisc.edu/badgerloop-earns-innovation-award-hyperloop-competition/

Photos: Renee Meiller

CORPORATE DAYS ON CAMPUS

In ongoing efforts to introduce engineering students to the companies that someday might employ them, the college hosted Oshkosh Corp. and Georgia-Pacific for early-fall days on campus. Representatives from the companies showcased their technologies, offered both technical talks and more general information sessions, and chatted with students about everything from workplace culture to manufacturing processes to the internships, co-ops and full-time positions they had available.

If your company would like to learn more about the benefits of hosting a day on campus, contact Justin Hines, college corporate relations manager, at jhines3@wisc.edu or (608) 262-0578.

RACING, AHEAD

The UW-Madison Society of Automotive Engineers (SAE) Formula Team, known as Wisconsin Racing, is made up of nearly 100 students who participate in some capacity, with a core group of approximately 40 students. It has two teams, a combustion team and an electric team, the latter debuting in 2017. Each May, the team competes alongside 120 teams from around the world in the Formula SAE World Championship, held annually at Michigan International Speedway.

Members build a new vehicle each year, which affords them the freedom to design anything they desire if they're able to acquire the resources and knowledge necessary. For example, in the past few years, the team created its first electronic clutch actuation, servo-actuated electric shifting, carbon fiber monocoque chassis, novel engine controls, lightweight aerodynamics package, and sophisticated electronics.

To fund their endeavors—to the tune of approximately $100,000 annually—members recruit corporate sponsors and pitch to private organizations. It's an entrepreneurial endeavor that allows members to learn important "soft" skills as they train to become the next generation of automotive engineers and business people.

As they build and refine their vehicles and work toward competition-readiness, students pose questions and discover answers just as they will be doing as professionals. Through this process, they cultivate a strong engineering intuition very quickly, making them highly pursued by automotive, aviation, and space industries. For instance, Wisconsin Racing alumni have gone on to careers at Chrysler, Ford, NASA, Tesla and Space X.

Photo: Stephanie Precourt

Steve Krug, a Wisconsin Racing alumnus (BSME '16) who was recruited by Tesla, says the work designing structural hardware, manufacturing, analyzing data and simulating vehicles he did with Wisconsin Racing translated directly to work he later did during internships and now at Tesla. "Wisconsin Racing fosters core members who are invaluable in the workplace based on their ability to get things done, be smart, communicate effectively, and aim to have fun in the process," Krug says.

Read a longer version of this story at www.engr.wisc.edu/students-sae-formula-team-seize-opportunity-grow-professionally/

ASTRONAUT SCHOLAR AIMS HIGH

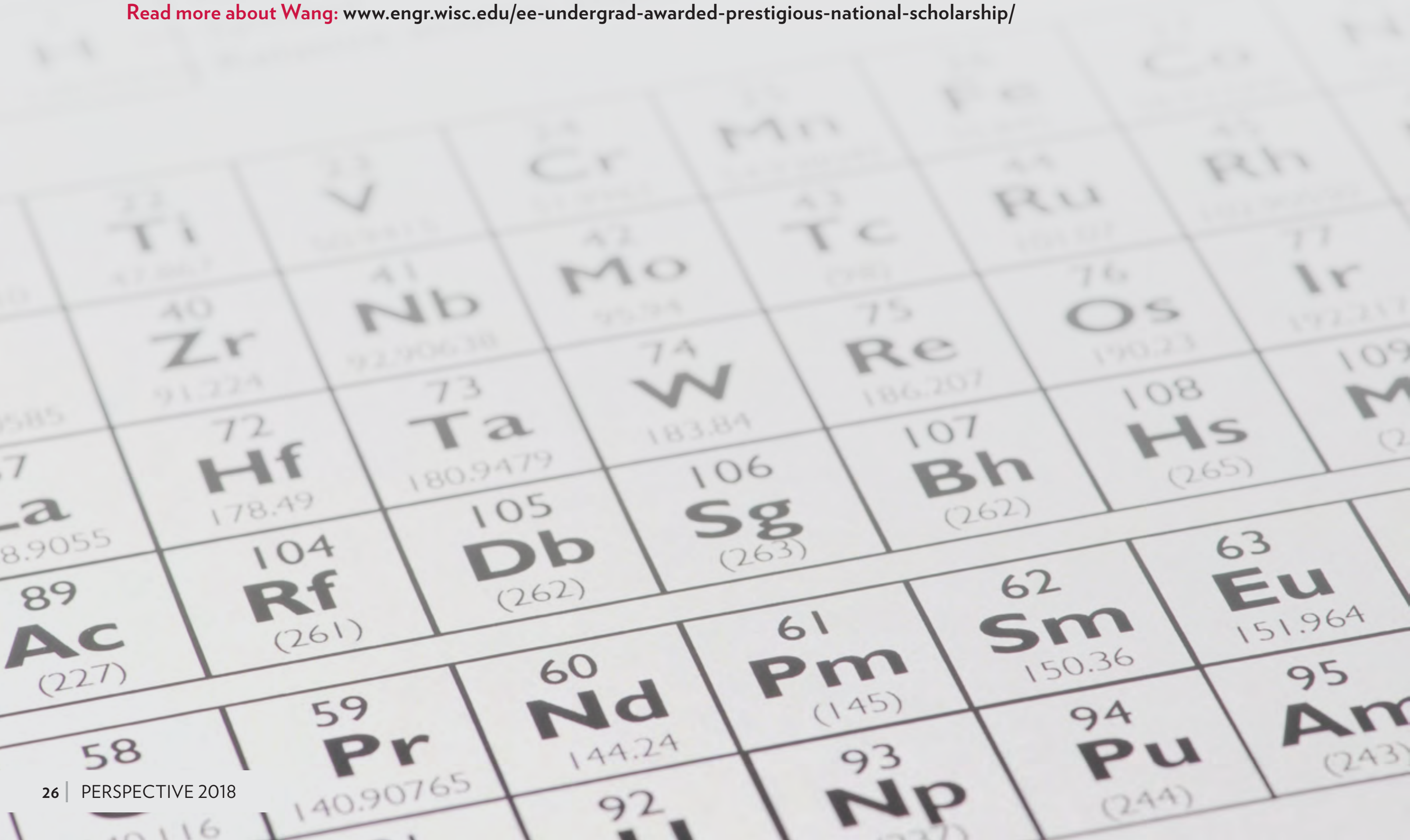
Photo: Stephanie Precourt

Madison native Nathan Wang began his first research internship in the laboratory of Chemistry Professor Gilbert Nathanson the summer after his junior year in high school. Next, he chose the lab of Lih-Sheng (Tom) Turng, the Kuo K. and Cindy F. Wang and Vilas Distinguished Achievement Professor in mechanical engineering, at the Wisconsin Institute for Discovery. And before he had even completed his freshman year at UW-Madison in spring 2016, he was on his third lab rotation with Sean Palecek, the Milton J. and A. Maude Shoemaker Professor in chemical and biological engineering.

Wang now is double-majoring in chemical engineering and biochemistry, with a certificate in computer sciences. He's still working in Palecek's lab, and, in recognition of his already stellar academic and research record, was among a handful of individuals around the country selected to receive a prestigious astronaut scholarship.

Originally established more than 30 years ago by the six surviving astronauts of NASA's Mercury Seven mission, the Astronaut Scholarship Foundation awards merit-based scholarships to the best and brightest university students in science, technology, engineering and mathematics (STEM) programs. Wang received the scholarship at a ceremony in Washington, D.C., in September 2017.

Read more about Wang: **www.engr.wisc.edu/ee-undergrad-awarded-prestigious-national-scholarship/**



ARMY ACHIEVER

On Aug. 30, 2017, Kai Pederson, an Army ROTC cadet, a junior studying electrical engineering, computer sciences and math received a prestigious Distinguished Achievement Scholarship of $4,000 from the Congressional Medal of Honor Foundation, in partnership with the Armed Forces Communications and Electronics Association.

Pederson, of Waconia, Minnesota, is the first cadet from Madison to participate in the West Point Cyber Leader Development Program. The program seeks to identify and develop cyber leaders.

Pederson says he grew up dismantling and assembling computers as a hobby and wants to use his cyber skills to make the country safer. He's already helping the university be more secure—he works for the UW-Madison Office of Cybersecurity, protecting university information. He also volunteers weekly as a tutor at Madison East High School.

Read more about Pederson: www.engr.wisc.edu/ee-undergrad-awarded-prestigious-national-scholarship/

NUCLEAR MATERIALS RESEARCH, WITH GUSTO

Calvin Parkin spends his days blasting high entropy alloys with radiation.

Photo: Stephanie Precourt

And to fund his efforts to identify nuclear reactor materials that can stand the test of time, the first-year engineering physics graduate student received a Department of Energy (DOE) research fellowship from the Nuclear Energy University Program.

Conventional alloys, which typically are made of a primary atom with small additions of other atoms, have limited lives because high-energy radiation changes their structure in a manner that alters important properties like strength or stretchability. Parkin hopes to discover a new alloy that combines many different elements in about an equal number of atoms and, through that combination, is resistant to changes due to radiation.

In his research, Parkin is using heavy ions instead of the neutrons in nuclear reactors because the ions provide a much better idea of the amount of damage sustained after a 60- or 70-year lifetime in a shorter amount of time. "We're looking for alloys that can withstand high levels of radiation damage in fast reactors because the fast neutrons are much more damaging than in thermal reactors," he says. "We want to see if we can find something just crazy-good."

MEET ANDREW LAMBERT: 2017 WINSLOW SARGEANT GRADUATE FELLOW

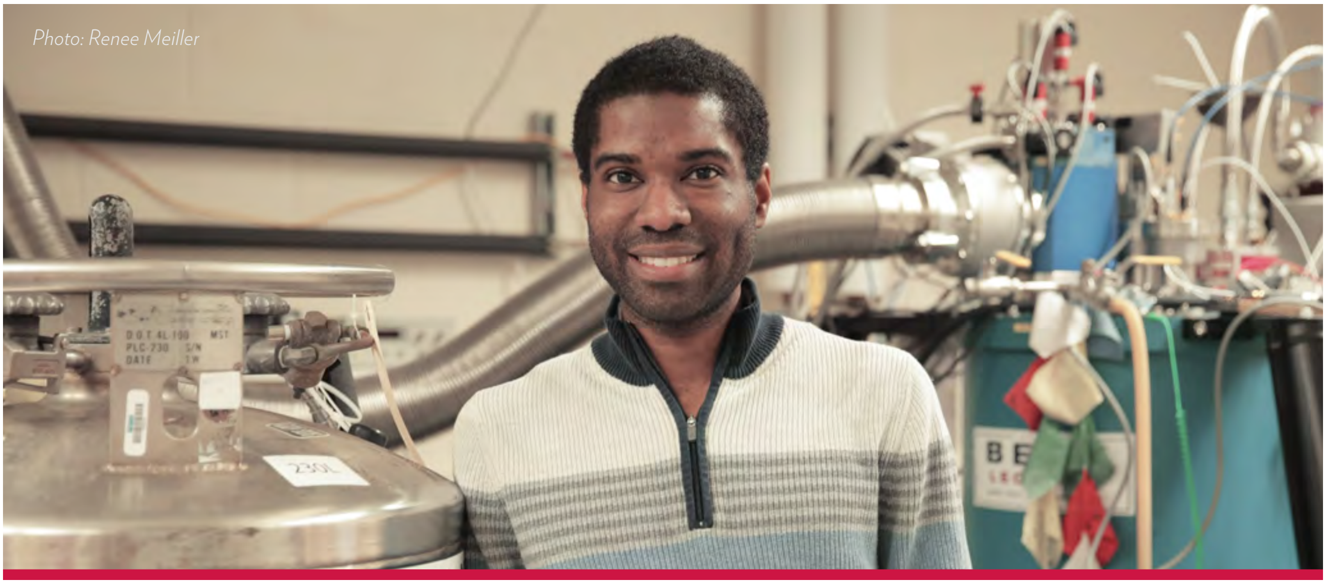


Photo: Renee Meiller

Andrew Lambert is exactly the type of graduate student that alumnus Winslow Sargeant (PhDECE '95) had in mind when he established a graduate fellowship. The prestigious fellowship awards a generous financial package to a highly motivated African-American PhD student in electrical and computer engineering. Lambert, who is also a past recipient of a GEM Consortium fellowship, has demonstrated that drive for success in his time at UW-Madison.

While in pursuit of his master's degree, Lambert interned at Intel Corporation during the summer, and performed research on experimental quantum computing during the academic year. A native of Spring Valley, New York, he received his bachelor's degree in electrical and computer engineering from the New York Institute of Technology and a master of engineering degree from the Rochester Institute of Technology.

Lambert says his decision to move to Madison rested on the schools reputation as a research leader in quantum computing. "Madison has a strong effort in this area of research and is well-equipped with labs to fabricate the devices for the study of quantum computing," Lambert says.

His research is focused on engineering quantum bits ("qubits"), which will then be used to construct a quantum computer. "Quantum computers will enable us to solve problems that are intractable to current computing technologies," Lambert says. "This new class of computers will enable many breakthroughs in STEM fields."

Quantum computing has been the subject of theoretical research for decades, but the ability to build quantum computers—which would be vastly more powerful than current computing systems that depend on a binary bit structure—for wide use remains in its infancy.

Lambert's successful scholarship record and his progress toward building quantum bits has in part depended on the Winslow Sargeant Graduate Fellowship. Lambert says that the fellowship, which covers expenses related to tuition, healthcare and fringe benefits, and provides a stipend, is currently his sole source of funding.

The fellowship, which is intended to encourage African-American scholars to pursue an advanced engineering degree, is an important part of a wider grassroots effort that Lambert says is needed to make such scholarship a realistic possibility for the broader African-American community.

"The best way to build those opportunities is to have a strong effort on rebuilding the low-income black communities and focus on people in high school and younger," Lambert says. "For example, have extracurricular activities, an aggressive and competitive public-school system, and reestablish the importance of education by exposing youth to higher education and labs, as well as what can be accomplished if education is pursued."

RAJA TIMIHIRI:
AN AMBASSADOR FOR ENGINEERING ETHICS

Electrical and computer engineering PhD candidate Raja Timihiri's research is focused on power system optimization, but she also has a keen interest in the ethical implications of engineering research and technology. Timihiri received a fellowship funded by Dave (BSECE '76, MSECE '78) and Sarah Epstein to develop modules for an ethics in engineering course. We spoke to Timihiri about how her interests in course design and ethics led her to enthusiastically take on the task.

Raja Timihiri's research is focused on power system optimization, but she also has a keen interest in the ethical implications of engineering research and technology.

How did you become interested in developing the ethics in engineering modules?

I was first interested in applying for the Epstein fellowship because of the course design component; I had recently been part of teaching and designing online course components for an introductory course for undergraduate engineering students. I quickly realized that this fellowship wouldn't be just about course design. It has a nobler goal: introducing ethics to students in engineering. We started putting together introductory material on ethics that emphasizes the importance of ethical awareness in engineering and technology design. We're aiming to develop a mini course in ethics that allows undergraduate students to fully appreciate the seriousness of the ethical dilemmas that can face all engineers.

Why is an ethical approach to engineering important to you?

I believe that ethics are part of everyday life. Many issues today aren't considered or labeled ethical issues but in fact have ethical dimensions. For instance, distracted driving is a serious safety issue, but it's also an ethical issue. One popular topic these days is that of automated vehicles or self-driving cars. While this technology has the potential to speed traffic and decrease accidents due to human factors, it has many ethical issues that aren't usually considered. In fact, the ethics module I'm currently working on involves a case about the ethical implications of self-driving cars.

We hear a lot on the news about companies introducing their version of a self-driving car in cities across the country. At first look, this sounds very exciting, especially for engineers. But we also hear about several instances where these vehicles didn't perform as expected, leading to several fatalities. A major ethical issue is the decisions that the vehicle's algorithms will be making about collisions. For instance, if an automated vehicle (AV) is about to crash into a motorcyclist, should it be programmed such that it saves the motorcyclist's life by instead crashing into a barrier? How about if doing this further risks the lives of the passengers in the car? Whose lives ought to be prioritized? Whose ethical responsibility is it to make such decisions? Can we ever create an "ethical algorithm" and what would such an algorithm actually do? Is it the engineers' responsibility to program an "ethical" algorithm? If not, whose responsibility is it?

What do you hope the course achieves?

We aim to increase students' ethical awareness and introduce some decision-making tools that can be useful in starting to answer some of these ethical questions. Most of the time there isn't a clear-cut solution that would satisfy all parties involved. But there's a process that must be followed to make sure that harm is minimized and safety is held above profit.

COUNTING CRANBERRIES: A TECHNOLOGICAL TWIST ON AN AGE-OLD PROCESS

It's a quintessential cranberry scene: Thigh-deep in a flooded bog full of millions of floating berries, two farmers extol the merits of products made from the tart red fruit.

Most of the year, however, the bog is dry and the ripening cranberries are nestled among a dense tangle of woody, low-growing vines.

That's when people like Ben Tilberg start counting cranberries.

"When we do crop estimations, we pick all of the fruit in a square-foot area and then we hand-count the berries," says Tilberg, a Babcock, Wisconsin-based scientist with the grower-owned cooperative Ocean Spray Cranberries. "There might be anywhere from 300 to 500 berries per square foot, and we count hundreds of squares each crop year."

It's a time-consuming, laborious endeavor—but one that yields important information about everything from berry quality to the projected harvest. "We freeze almost the entire crop and cranberries are processed throughout the year," says Tilberg. "Not only do we need to gauge our freezer capacity, we also want to make sure the best fruit goes into the freezer."

In big cranberry-producing states such as Massachusetts and Wisconsin, that's a big deal: In fact, with 21,000 acres of cranberry bogs in 20 counties, Wisconsin not only is the nation's top cranberry producer, it produces more than half of all cranberries in the world.

The sheer labor involved in counting cranberries the old-fashioned way prompted Tilberg to pursue a more efficient, technologically advanced method. After reading news stories about imaging techniques used to study rainforests, he contacted UW-Madison electrical and computer engineering professors Susan Hagness and John Booske with his idea.

"It was sort of a microwave radar concept he was envisioning," says Booske.

The result: a new device that essentially automates the counting process, without having to pick any berries, and the potential to paint a more accurate picture of the crop and the harvest as a whole.

To create the device, Hagness and Booske worked with electrical and computer engineering PhD student Alex Haufler to conduct feasibility studies in their lab. Those results were promising enough for the researchers to secure grants from the Wisconsin Cranberry Board and Ocean Spray.

"The funding has enabled us to develop a microwave-based cranberry sensing technique," says Hagness.

The team's first-generation prototype—a small box-shaped device suspended above a square-foot section of cranberry bed—draws on technology similar to that used in medical imaging and weather radar. "We transmit a microwave signal that is reflected back from the cranberry bed, and the strength of the reflected signal indicates the number of berries within the canopy," says Haufler.

In weather radar, says Haufler, the strength of the reflected signal indicates how much water is contained within the clouds. That holds true for cranberries, also. "The cranberries have a significant water content compared to the surrounding stems and leaves, making them more responsive to the microwaves," he says.

In early fall 2017, Haufler joined Tilberg in plots at the Dubay Cranberry Co. of Junction City, Wisconsin, and the Remington Cranberry Co., of Necedah, Wisconsin, to conduct a preliminary round of data collection using the prototype sensing device. Located in the heart of cranberry country in Central Wisconsin, both farms are members of the Ocean Spray cooperative.

The researchers' first prototype, in the bog.

A substantial portion of Tilberg's job is working directly with growers on everything from nutrient and pest management to fruit quantity and quality. He says growers easily would be able to use the device to scan an entire cranberry bed. "They want to know what areas of their beds produce higher or lower yields, and why that is," says Tilberg. "Accurately mapping the bed gives us a starting point."

Ocean Spray has a longstanding research relationship with UW-Madison. And as a researcher, Tilberg also collaborates closely with cranberry geneticist Juan Zalapa, the USDA associate professor of horticulture at the university who also helped to inform the device's development. Zalapa's aim is to develop new cranberry varieties that offer increased yield; improved quality, taste and nutritional content; and better response to factors such as extreme weather, insects

and disease pressure. "We have to select from thousands and thousands of genotype clones," says Zalapa. "We identify promising ones by collecting yield and quality data."

Zalapa's living "laboratory" consists of hundreds of 5-by-5-foot cranberry plots—all of which annually require a crew of 10 people many days—or even weeks—to hand-harvest and count fruit. He says the new technology could be a huge boon not only for his research, but for the industry as a whole. "I'm very interested because this will greatly impact the development of new varieties," he says. "Cranberry growers don't all plant one and the same variety, but there are many choices and this kind of technology can help growers adopt new varieties or pick multiple varieties that can be sustainable and produce well in their particular operation. It would really change my work and change the industry for yield prediction purposes."

Using the data he collected in fall 2017, Haufler now is optimizing the algorithms used to convert the measured microwave signals into estimates of cranberry numbers and improving the technology so that it's ready for another round of testing in 2018.

For that phase, the team is planning to attach the device to a boom, or long cabled beam, that extends 80 feet out over a cranberry bed. "If we can attach this microwave sensing unit to the boom, we'd be able to stop at multiple areas across the bed and take measurements," says Tilberg. "We could take as many measurements as we wanted, and we'd be able to accurately estimate yield across the entire marsh."

Ultimately, says Hagness, the goal is to transfer the technology directly into the hands of the people who will benefit from it. "I think there's a mechanism down the road for this to be accessible to any grower," she says.

Photo: Jeff Miller

TALL STRAWS

In the forests of central and northern Wisconsin, there's a lively give and take between trees and the groundwater they need to thrive. Until now, however, nobody has known exactly how thirsty those trees really are.

Steve Loheide

"When managing groundwater it's critical that you account for all users, but currently, we don't have good estimates of direct groundwater use by forests," says Steve Loheide, an associate professor of civil and environmental engineering. "Having an idea of how much groundwater they're using is, to put it mildly, important."

Loheide and graduate student Dominick Ciruzzi are studying how much groundwater forests use—and how the changing levels of available groundwater may be affecting the trees' growth over time.

The project is focused on two specific areas of Wisconsin: The temperate highland forests of Wisconsin's Northwoods near Minocqua and forests in the Central Sands region, both of which happen to feature sandy soil that can't retain water as effectively as other soil types do. In this study, the Northwoods will serve as the baseline that will help researchers understand what's going on in the Central Sands region, an area centered on Portage, Adams and Waushara counties that's recently seen an increase in groundwater use by high-capacity wells.

Like most plants, trees survive on shallow soil moisture, only resorting to using groundwater when they don't have enough soil moisture available, in years with low precipitation. To gauge how much groundwater trees and forests are using, Ciruzzi, who's been based at the Trout Lake Research Station near Minocqua since 2015, plans to monitor wells—10 in the Central Sands region, 15 near Trout Lake—to examine and measure the size of daily fluctuations in the water table. The bigger the fluctuations, the more groundwater is being used by the trees.

While using wells to track water-table fluctuations covers the present, Loheide and Ciruzzi's sights are set higher. Another key aspect of the project looks to tie current groundwater use to the trees' past groundwater use. Ciruzzi is also collecting cores from the trees in both regions—cores so small they can be stored in a drinking straw—and measuring the growth rings. When the growth rate is low, it's an indicator of a dry year and deep groundwater.

Ultimately, the team's research could have an impact on forest management strategies, including influencing where future forests are planted and where existing forests might be maintained or removed. It's also likely to have an impact on the ways in which groundwater managers and local farmers allocate groundwater resources.

"The effects really go two ways," says Loheide. "There's the effect that the forests are having on the groundwater system by using it and changing water levels on their own, and then there's the effect changing water levels are having on the forest."

ENGINEERS' DAY AWARD RECIPIENTS

At the 70th annual Engineers' Day banquet, held Oct. 20, 2017, the College of Engineering honored 10 outstanding alumni—three of whom are early in their careers and already have made exceptional contributions. These award recipients work in areas ranging from corporate leadership and entrepreneurship to academia and engineering. They are thoughtful engineers; creative, bold thinkers; and certainly, outstanding leaders. This diverse group of people includes educators, entrepreneurs, and executives—and their work continues to make a difference in the lives of countless people.

Distinguished Achievement Award

Stephen Spiegelberg
President and Co-Founder, Cambridge Polymer Group
BSChE '88 (PhDChE '93, MIT)

We honored Stephen for foundational developments in polymeric materials design, testing and processing methods that have greatly impacted the biomedical, chemical and food industries.

Alain Henri Peyrot
Retired President, Power Line Systems
MSCEE '66, PhDCEE '68

We honored Alain for exemplary achievements as a structural engineer, faculty member, entrepreneur, philanthropist and UW-Madison alumnus.

Adam Diedrich Steltzner
Engineering Fellow, CalTech/NASA Jet Propulsion Laboratory
Chief Engineer, Mars 2020 Project
PhDEM '99 (BSME '90, UC-Davis; MS applied mechanics '91, Caltech)

We honored Adam for pioneering accomplishments that have yielded new ways to explore and expand the knowledge of our universe.

Daniel J. Piette
Board member, Petroleum GeoServices
BSMineE '80

We honored Dan for career-long leadership in mining engineering and big data, which has helped introduce new technologies to the energy industry.

Denita Willoughby
Vice President, Sempra Energy
BSIE '88 (MBA Harvard)

We honored Denita for her inspiring track record in sales, supply chain management and government affairs and for her passion for developing leaders and improving education among youth.

Sharon Farrens
Director of Process Integration, Quora Technology Inc.
MSNE '83, MSMatSci '85, PhDMatSci '89
(BS physics '81, Nebraska Wesleyan University)

We honored Shari for pioneering significant innovations in wafer bonding and advanced packaging technologies that are critical processing steps in semiconductor device manufacturing.

Christine M. Schyvinck
CEO, Shure
BSME '89 (MBA engineering management '99, Northwestern University)

We honored Chris for her leadership in microphones and the audio electronics industry, which has led to exceptional results in product quality and corporate profitability.

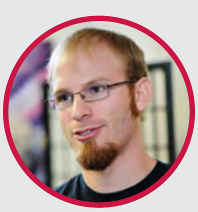
Early Career Achievement Award

Nidhi Aggarwal
Founder, Qwiklabs
MSEE '06 (PhDCompSci '08)

We honored Nidhi for exemplary leadership and engineering innovation in the cloud computing and learning sectors, and for vigorous support for diversity in engineering education and practice.

Ross Radel
President, Phoenix Nuclear Labs
BSNE '03, MSNEEP '04, PhDNEEP '07

We honored Ross for corporate leadership that has led Phoenix Nuclear Labs to become an internationally recognized manufacturer of neutron sources for medical diagnostics and detecting clandestine materials.



Christopher M. Meyer
Director, Sector 67 Inc.
BSME '08, MSME '10

We honored Chris for leadership in achieving a unique vision of education, entrepreneurship and community development through Sector 67, which has enabled more than 100 companies and entrepreneurs to turn their ideas and dreams into reality.

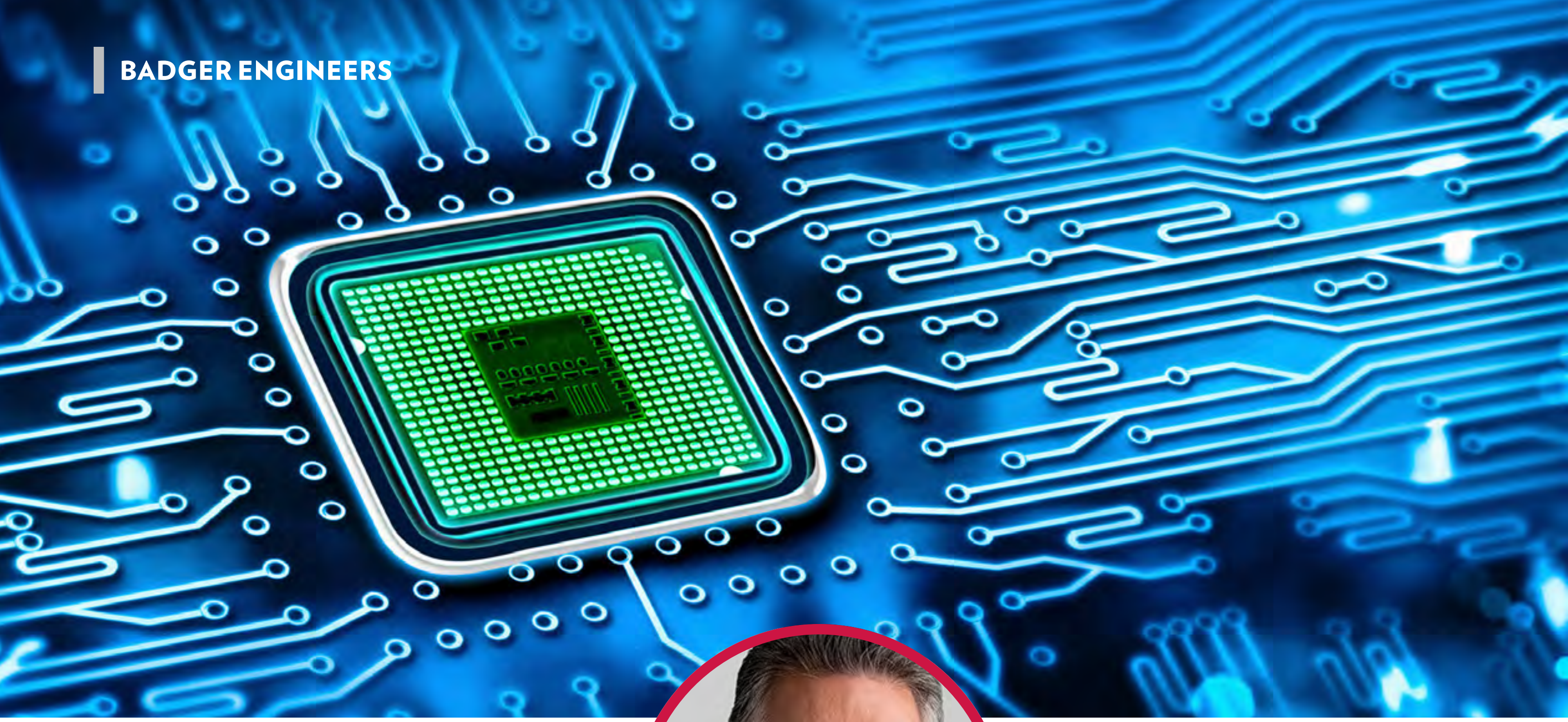
WAA HONORS MECHANICAL ENGINEERING ALUM

Jim Berbee (BSME '85, MSME '87, MBA '89) was among four UW-Madison alumni to receive a distinguished alumni award from the Wisconsin Alumni Association in October 2017.

Berbee is a clinical assistant professor in the UW School of Medicine and Public Health and an emergency physician at the William S. Middleton Memorial Veteran's Hospital. He started his career as an IBM systems engineer, and in 1993, he founded Berbee Information Networks Corporation in his basement. As the business grew, clients included IBM, Microsoft and Cisco.

A four-time Ironman triathlete, Berbee once broke his collarbone during training, and the care he received inspired an interest in emergency medicine. After selling his highly successful business to the public company CDW in 2006, he attended the Stanford University School of Medicine and earned his MD in 2010. He subsequently completed his residency in emergency medicine at the UW Hospital and Clinics.

Berbee is also the founder of the Berbee Derby Thanksgiving Day 10K run and 5K run/walk. Proceeds support the Technology Education Foundation, which provides resources to those who are especially vulnerable to the technology gap. Berbee is a trustee for the Wisconsin Alumni Research Foundation, the Morgridge Institute for Research, and WICell Research Institute.



FOUR QUESTIONS WITH ALUM MIKE SPLINTER ABOUT SEMICONDUCTORS

In February 2017, electrical and computer engineering alumnus Mike Splinter (BS '72, MS '74) was among the 84 new members and 22 foreign members elected to the National Academy of Engineering.

Election to the NAE is among the highest professional distinctions accorded to an engineer. The academy recognized Splinter's leadership in advancing semiconductor manufacturing, quality and equipment.

Splinter retired in 2015 as chairman and CEO of Applied Materials and currently is co-founder and general partner of Los Altos, California-based WISC Partners, which provides strategic operating capital to promising Wisconsin entrepreneurs.

He is known as an innovator in electronics technology, as well as in photovoltaic cells and solar solutions to reduce fossil fuel use. In fact, the Semiconductor Industry Association credits Splinter with transforming photovoltaic cell production from a "boutique" industry into a meaningful source of renewable energy.

As leader of Applied Materials, Splinter also infused community service opportunities throughout the company and in his personal activities. This commitment to community service includes supporting food banks, launching a program to invest in local schools, and working with the Clinton Global Initiative to bring electricity to villages in rural India.

Before joining Applied Materials as CEO in 2003, Splinter worked for 20 years at Intel Corp., during which time the company became a leader in microchip technology. He previously held positions at the Rockwell International electronics research center.

Splinter serves on several influential industry boards, including NASDAQ, US-India CEO Forum and Technology CEO Council, SEMI, Pica 8 Inc., and the University of Wisconsin Foundation.

Semiconductor materials have enabled countless important advancements in the field of electronics, and we asked Mike to talk with us about the semiconductor industry in the United States.

1 *What is a semiconductor, and what impact have semiconductors had in our lives?*

It is hard to fathom the impact semiconductors and semiconductor technology has had on our lives as individuals and as a society. There have been waves of impact from the personal computers, to the Internet, to the cell phone and smartphone and now social media and the IOT, or Internet of Things.

Semiconductors are the base material in computer chips, LED lighting, solar cells, high-power devices, enabling electric cars and windmills and much, much more. As I think about the future there is so much more to come that will not only change the way we live, work and play but even more fundamentally, as we strive to create the computing power to complete some of the fundamental understandings of human beings and the universe.

There are very exciting times ahead in technology and semiconductors and computer chips will be at the foundation of creating new waves of technology.

2 *What role can education play in advancing the semiconductor industry?*

One fact that every University of Wisconsin student should know is that John Bardeen, a UW graduate, was one of a three-man team that invented the basic element of every computer chip, the transistor.

Education has always had a major role but today it has an expanding role in technology to create a broader and broader array of engineers and computer specialists. While I strongly believe Moore's law will continue for the next 10 years or more (Moore's law says the transistor density will double every 24 to 36 months), I worry that there are not enough engineers truly focused on the combination of chemical engineering, materials science and electrical engineering that can make the most fundamental advancements that are necessary to keep Moore's law alive.

I also worry that those fundamental advancements will not be made in the U.S. These new engineers of the 2020's need to have that drive, breadth and curiosity that will push them to solve the tough problems of the future and the entrepreneurial spirit to take the risks necessary to bring those new capabilities to market. This is more true today than at any time in the past.

3 *What challenges is the industry facing and why?*

There are many challenges but today the shortage of quality engineers and software experts is at the top of the list. We need more and better human capital dedicated to this industry. The number of engineers has been growing in the U.S. but it is still not enough.

There are other very tough problems at the atomic and subatomic level. There are major issues with security of data and privacy but if we have the right talent applied to the problems I have every confidence they will be solved.

4 *How can the United States ensure it remains competitive in (or a leader in) this industry?*

A subcommittee of the President's Council on Semiconductor Technology, on which I served, created an outline of the necessary R&D investments at the government level and in education to keep the U.S. leading the world in semiconductor and computer technology.

Our basic premise was twofold:

- We have to keep the treadmill going—and going fast, creating the next generations of computer architecture and artificial intelligence capabilities.
- Secondly, we have to be very diligent on protecting the IP of our companies and our country. With the right investment, education and spirit of the U.S. people, we have an opportunity to lead in this technology field for years to come.

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UNIVERSITY OF WISCONSIN–MADISON

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SHUTTLE VISIT UNDERSCORES OUR LEADERSHIP IN AUTOMATED VEHICLE RESEARCH

As a leader of one of 10 United States proving grounds for self-driving vehicles, we are advancing the state-of-the-art in this revolutionary form of transportation. Wisconsin Gov. Scott Walker named Civil and Environmental Engineering Professor David Noyce and researcher Peter Rafferty to the state's new steering committee on autonomous and connected vehicle testing and deployment. And in November 2017, we showcased a Navya driverless shuttle on campus and at locations around Madison.

Learn more about the proving grounds at: wiscav.org

Read more about our AV research: www.engr.wisc.edu/first-ever-driverless-vehicle-debut-nov-15-18-madison/

Photo: Renee Meiller