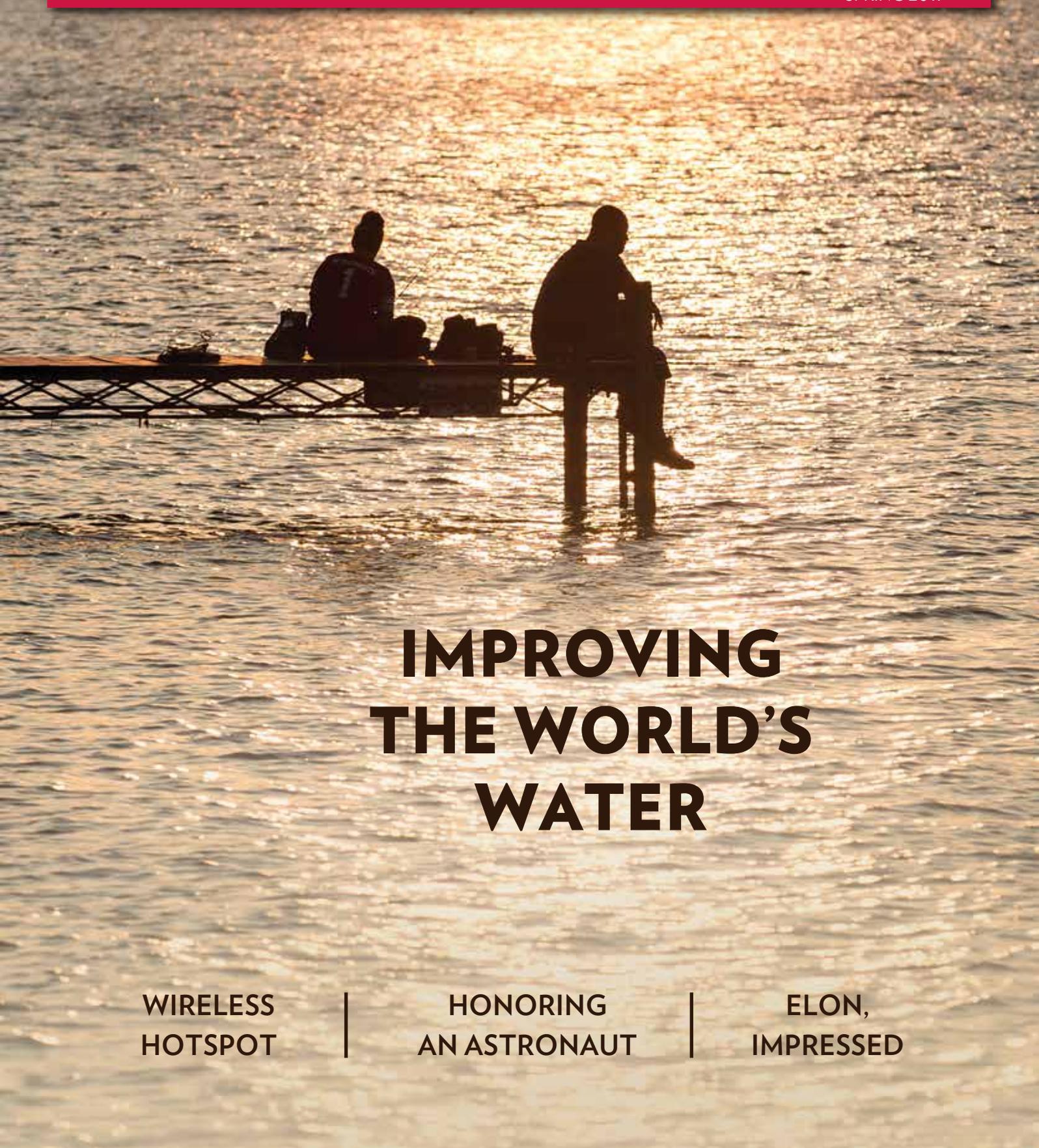


PERSPECTIVE

SPRING 2017



IMPROVING THE WORLD'S WATER

WIRELESS
HOTSPOT

HONORING
AN ASTRONAUT

ELON,
IMPRESSED



FEATURES

10 GLASS HALF FULL
IMPROVING THE WORLD'S WATER



In Vilas Distinguished Professor of Civil and Environmental Engineering Katherine (Trina) McMahon's research group, students study the microbial ecology of natural system such as lakes, as well as engineered systems. Broadly, they aim to improve capacity to predict and model microbial behavior, while searching for novel biologically mediated transformations that can be harnessed for engineering applications.



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UW-Madison researchers are fast becoming leaders in technology to enable an increasingly interconnected world

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PERSPECTIVE

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ENGINEERING EXTERNAL RELATIONS

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GREETINGS, ALUMNI AND FRIENDS!

As you might imagine, I have the opportunity to travel quite often to attend professional meetings and conferences, visit our industry partners, and meet our alumni and friends in their cities and homes. And I'm often asked, "What's happening at Wisconsin?"

It's a question I greatly enjoy hearing, in part because there's so much to tell.

At the university level, demand for a UW-Madison education is at an all-time high, and our engineering enrollments at both the undergraduate and graduate student level reflect our students' very strong belief in the high quality of our engineering degrees. Looking at this quality from a different perspective, the organizations that hire our students recruit here because of our national and international reputation for producing well rounded, well educated engineers with outstanding communication, problem-solving and technical skills. Each year, our Engineering Career Services office works with approximately 1,000 employers who offer some-6,500 professional jobs through online postings and on-campus recruiting. In fact, one very easy way to remain involved in the College of Engineering is to hire our students or encourage your company to recruit here.

With your support, we are engaged in constant efforts to improve the educational experience we offer our students—and that means everything from what they learn and the environment in which they learn to the out-of-classroom opportunities available to them. For example, through the many generous gifts to our Dean's Fund for Innovation, we have transformed many of our outdated, lecture-only-style classrooms into modern, technology-rich spaces that facilitate discussion and deeper exploration and understanding of course concepts. And with part of a \$22 million commitment from The Grainger Foundation, we are renovating two floors of our Wendt building to create interactive classrooms, group study spaces, and the Grainger Engineering Design Innovation Lab—a "makerspace" that will offer high-tech fabrication, visualization and prototyping facilities (to complement our already outstanding engineering student shops) so that our students, faculty and staff can realize even the most intricate, creative designs.

At UW-Madison and within the College of Engineering, we know that state support is just one of many resources available to us—and thus, we have committed to be innovative as we focus on a diverse array of revenue streams that will allow us to continue to grow and excel in our research, teaching and service to society.

In 2013, UW-Madison kicked off a \$3.2 billion fund-raising campaign—the largest in university history—and our alumni have responded with an outpouring of support. One example of the impact of gifts made through the campaign is an increase in our ability to recruit and retain top faculty. We have expanded the number of named professorships and scholar awards available to our faculty to 59 within the college, in addition to 59 awarded by the university. The prestige associated with all of these named awards enables us to honor star faculty, while the funding they receive amplifies their activities in research and teaching.

If you turn to the back cover of this magazine, you will see photos of 16 young faculty members who recently joined our college. We are very excited about the enthusiasm and expertise they bring the college—and your gifts are instrumental in our ability to provide competitive startup packages that set these new faculty members up for success.

And as I said at the beginning of this message, our faculty, staff and students are enjoying a great deal of success. Recently, for example, an interdisciplinary team of undergraduate students earned a coveted innovation award in the international Elon Musk-sponsored Hyperloop Competition. Two of our students were named prestigious Goldwater Scholars, and another won first place in a GE competition that challenged entrants to accomplish an impossible task. Our transportation researchers recently were tapped to be at the forefront of national efforts to test driverless vehicles. A materials engineer developed unique flooring that harvests energy, while mechanical engineers are using technology to harness the energy you generate simply by walking around. Our biomedical engineers are advancing personalized cancer treatment and exploring the benefits of revolutionary gene-editing tools. One of our electrical and computer engineering faculty members is perfecting a self-correcting contact lens that can automatically focus both near and far.

As you can see from these examples, as well as the many stories throughout this magazine, UW-Madison engineers have the knowledge, tools, technology and creativity to make any dream possible, to make advances that improve our world.

What's happening in Wisconsin? All of these things, and more. And continuing all of this important work in research, education and service to society *is* possible with your support.

Thank you, and ON, WISCONSIN!



UW-Madison engineers have the knowledge, tools, technology and creativity to make any dream possible, to make advances that improve our world.

Ian M. Robertson

Ian M. Robertson, Dean
UW-Madison College of Engineering



Sangkee Min

NEW NANO-CUTTER *SLICES, DICES, CUTS, SCRIBES AND MILLS WITH UNPARALLELED PRECISION*



The College of Engineering is the new home of a unique machine that is capable of 3D milling precise to one nanometer. The machine, called the ROBONANO-0iB, is the first of its kind in North America, and it brings extremely advanced technological capabilities that could represent the future of advanced manufacturing. It is on a multi-year loan from the Japanese robotics manufacturer FANUC.

The ROBONANO's nanoscale cutting ability is two orders of magnitude more precise than most machines used in advanced manufacturing today. It has nearly limitless configurations for cutting, scribing and milling materials, and it potentially can handle emerging and existing materials in new and useful ways.

Those extremely precise capabilities offer exciting new research opportunities, and Sangkee Min, an assistant professor of mechanical engineering and a faculty member in the Grainger Institute for Engineering, hopes it will open up improved and novel approaches to the manufacturing of everything from semiconductors to toys and mobile devices to scientific instruments.

Min will use the machine's unique capabilities to explore its suitability for manufacturing emerging materials, as well as currently available materials. He also will explore how the machine can help open up new possibilities for manufacturing design; he hopes it will become one of the enabling technologies for a new manufacturing paradigm—what Min calls manufacturing for design. "I want to be able to ask the manufacturer, 'What is your perfect design?' and be able to provide that," says Min. "The opportunities are almost limitless for improving products and manufacturing processes with this machine."

More: www.engr.wisc.edu/advanced-nano-cutter-boost-emerging-materials-research-uw-madison/



LIQUID SILICON

SOUPED-UP COMPUTER CHIPS DO DOUBLE DUTY

When electrical and computer engineering faculty member Jing Li looks at a computer, she expects it to work, and work hard. She is creating fully morphable computer chips that can be configured to perform complex calculations, store massive amounts of information within the same integrated unit, and perform efficient communication across units.

She has named the new chips liquid silicon. “Liquid’ means software and ‘silicon’ means hardware. It is a collaborative software/hardware technique,” says Li. “You can have a supercomputer in a box if you want.”

The chips will pack a powerful computational punch, while being able to store significant amounts of data—tasks that require two entirely different types of hardware in modern computers. That separation makes our machines less efficient. “There’s a huge bottleneck when classical computers need to move data between memory and processor,” says Li. “We’re building a unified hardware that can bridge the gap between computation and storage.”

Her chips incorporate memory, computation and communication into the same device using monolithic 3D integration: silicon

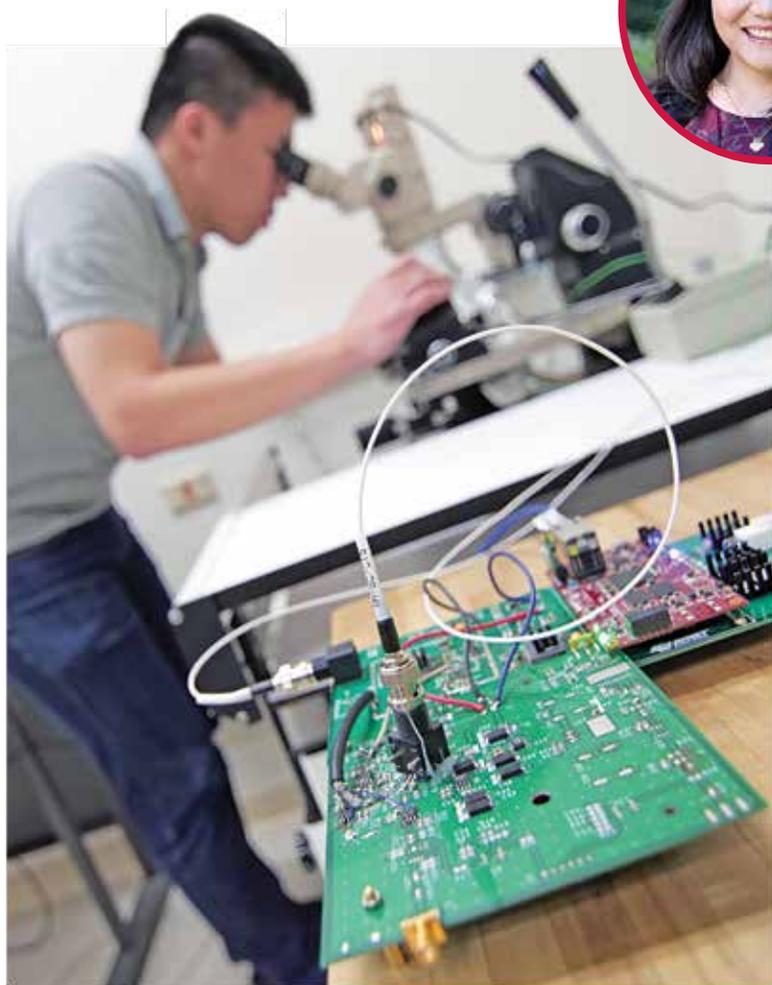
CMOS circuitry on the bottom connected with solid-state memory arrays on the top using dense metal-to-metal links. End users will be able to configure the devices to memory or computation, depending on what types of applications a system needs to run. “It can be dynamic and flexible,” says Li. “We originally worried it might be too hard to use because there are too many options. But with proper optimization, anyone can take advantage of the rich flexibility offered by our hardware.”

To help people harness the new chip’s potential, Li’s group also is developing software that translates popular programming languages into the chip’s machine code, a process called compilation.

To evaluate the performance of prototype liquid silicon chips, Li and her students established an automated testing system they built from scratch. The platform is so versatile that it can reveal reliability problems that even the most advanced industry testing setup typically cannot observe. That’s also why multiple companies recently have sent chips to Li for evaluation.

Given that testing accounts for more than half the consumer cost of computer chips, having such advanced infrastructure at UW-Madison will not only help make liquid silicon chips a reality, but also facilitate future research. “We can do all types of device-level, circuit-level and system-level testing with our platform,” says Li. “Our industry partners told us that our testing system does the entire job of a test engineer automatically.”

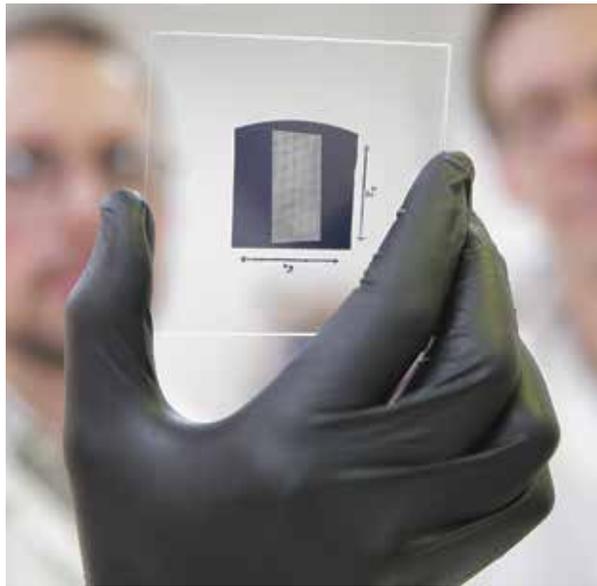
More: www.engr.wisc.edu/liq-uid-silicon-multi-duty-computer-chips-bridge-gap-computation-storage/



A NANOTECH MILESTONE CARBON NANOTUBE TRANSISTORS OUTPERFORM SILICON

For decades, scientists have tried to harness the unique properties of carbon nanotubes to create high-performance electronics that are faster or consume less power—resulting in longer battery life, faster wireless communication and faster processing speeds for devices like smartphones and laptops.

Now materials engineers Michael Arnold and Padma Gopalan, their students and collaborators have created carbon nanotube transistors that outperform state-of-the-art silicon transistors—an advance that could pave the way for carbon nanotube transistors to replace silicon transistors and continue delivering the performance gains the computer industry relies on and that consumers demand.



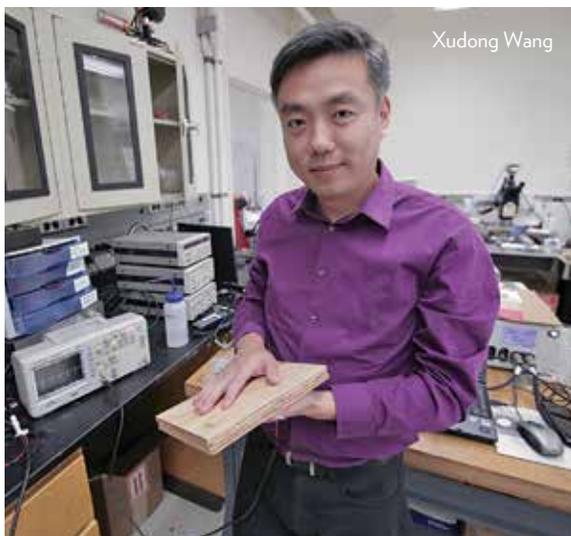
The new transistors are particularly promising for wireless communications technologies that require a lot of current flowing across a relatively small area—and the new carbon nanotube

transistors achieved current that's 1.9 times higher than silicon transistors. "This achievement has been a dream of nanotechnology for the last 20 years," says Arnold. "Making carbon nanotube transistors that are better than silicon transistors is a big milestone."

The researchers have patented their technology through the Wisconsin Alumni Research Foundation.

More: www.engr.wisc.edu/first-time-carbon-nanotube-transistors-outperform-silicon/

MOVE OVER SOLAR: The next big renewable energy source could



Flooring can be made from any number of sustainable materials, making it an eco-friendly option in homes and businesses alike.

Now, however, flooring could be even more "green," thanks to an inexpensive, simple method developed by materials engineer Xudong Wang, his graduate students, and their Forest Products Laboratory collaborators.

The method allows them to convert footsteps on the flooring into usable electricity by putting wood pulp to good use. The pulp, which is already a common component of flooring, is partly made of cellulose nanofibers. And, when chemically treated, the tiny fibers produce an electrical charge when they come into contact with untreated nano fibers. When the nano fibers are embedded within flooring, they're able to produce electricity that can be harnessed to power lights or charge batteries. And because wood pulp is a cheap, abundant and renewable waste product of several industries, flooring that incorporates the new technology could be as affordable as conventional materials.



A LANDMARK MOMENT

Located in the center of Bethlehem, the Church of the Nativity is a World Heritage Site and a major tourist attraction, particularly for Christians, because it is located atop the actual site where Jesus Christ is said to have been born.

But the structure itself is damaged and degraded; in 2008, the World Monuments Fund placed it on a watch list of the 100 most endangered world sites. In 2010, the Palestinian Authority announced plans for a multimillion-dollar restoration effort, the initial phase of which concluded earlier in 2016.

Professor part of effort to preserve an international treasure

The church's age (the original church was built in 339 A.D.) and many additions and iterations pique archaeologists' interest. And when a recent excavation came precariously close to undermining the support beneath a structural column within the Church of the Nativity's Hall of Saint Jerome, Palestinian authorities wisely called a halt to all digging until experts could assess the edifice.

Those experts—a team led by Professor Miguel Pando of the University of North Carolina at Charlotte and hailing from such diverse locales as Portugal, Peru and Wisconsin—traveled to Israel in July 2016 with one primary mission: Measure everything they could about the ancient building in order to protect it from damage.

Dante Fratta, an associate professor in geological engineering and civil and environmental engineering, was part of that team.

Each person brought unique knowledge and expertise; together, they spent a week placing sensors, measuring vibrations, scanning surfaces with lasers, and probing beneath the soil with ground-penetrating radar (GPR) and seismic waves. They created virtual three-dimensional maps of the hall that featured detailed descriptions of all cracks and damage, and they also installed a network of sensors that will monitor the church long-term and ensure it doesn't deteriorate further.

Support through the Civil & Environmental Engineering annual fund, which enables the department to respond quickly to emerging opportunities, helped make Fratta's participation in this important research possible.

More: www.engr.wisc.edu/professor-helps-preserve-ancient-church-nativity-bethlehem/

be right beneath your feet

Heavy traffic floors in hallways and places like stadiums and malls that incorporate the technology could produce significant amounts of energy, Wang says—and it could be easily incorporated into all kinds of flooring once it's ready for the market. He hopes to build an educational prototype in a high-profile spot on the UW-Madison campus where he can demonstrate the concept.

He already knows it would be cheap and durable. "Our initial test in our lab shows that it works for millions of cycles without any problem," he says. "We haven't converted those numbers into years of life for a floor yet, but I think with appropriate design it can definitely outlast the floor itself."

The Wisconsin Alumni Research Foundation holds the patent to the technology.

More: www.engr.wisc.edu/move-solar-next-big-renewable-energy-source-right-beneath-feet/

COMPUTATION MAKES MATERIALS DESIGN MUCH EASIER

By simulating substances inside the silicon brains of powerful computers, engineers Dane Morgan and John Booske and their students are finding ways to accelerate the arduous process of making new materials.

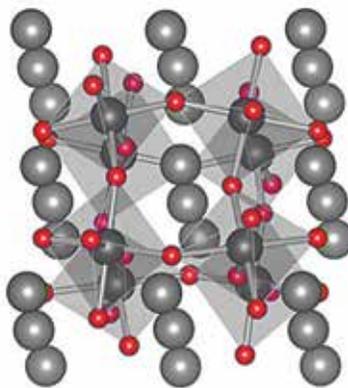
And using this approach, they identified a promising candidate compound—a perovskite that could be used in next-generation vacuum electronic devices. “If the measured material’s properties confirm what the models predict, this would be a very, very big advance,” says Booske, the Duane H. and Dorothy M. Bluemke Professor and a Vilas Distinguished Achievement Professor in electrical and computer engineering. “The resulting cathodes would enable high-power microwave amplifiers that cost less, have better efficiency, provide higher power at high frequencies, and can handle higher data rates. As a result, satellite wireless communications and TV services could be significantly improved while better radar and electronic countermeasure systems could better protect the lives of men and women serving in the armed forces during military conflicts.”

Synthesizing high-performance compounds is no trivial task—each attempt to mix molecules in the lab and measure the resulting properties costs money and takes time. So rather than spending unnecessary resources creating a cornucopia

of candidates that ultimately won’t work out, the researchers characterized virtual versions of materials to guide their experimental efforts.

Morgan, the Harvey D. Spangler Professor in materials science and engineering, was an early pioneer in implementing computationally guided materials design. “Calculations aren’t equivalent to doing an experiment, but for certain quantities you can get close to experimental accuracy with orders of magnitude increases in speed and reduction in costs,” he says. “It’s completely game-changing in terms of our ability to explore and design materials properties.”

The researchers filed a patent on the perovskite material through the Wisconsin Alumni Research Foundation. The U.S. Air Force Office of Scientific Research and the National Science Foundation funded the research.



More: www.engr.wisc.edu/game-changing-computational-approach-takes-guesswork-materials-design/

REVERSING REVERSING THE OUTLOOK: A NEW APPROACH TO STUDYING OVARIAN CANCER

With a unique approach that draws on 3D printing technologies, a team of biomedical engineering and medical researchers is developing new tools for understanding how ovarian cancer develops in women.

Ovarian cancer is difficult to detect in its early stages, which means doctors don’t usually diagnose it until late in the disease’s progression, after it has spread to other parts of the body. As a result, the five-year survival rate is only about 25 percent.

Led by Paul Campagnola, a professor of biomedical engineering and medical physics, the team aims to improve that outlook by understanding how ovarian cancer cells interact with nearby body tissue. The researchers will do that by implanting a 3D tissue model seeded with ovarian cancer into mice to mimic more closely the conditions of metastatic ovarian cancer in a woman. They’ll also develop new tools for imaging and detecting the disease. Ultimately, the team’s goal is to improve screening, diagnosis and treatment of ovarian cancer.

One of the most effective ways to improve the outlook for women with ovarian cancer is to develop a straightforward

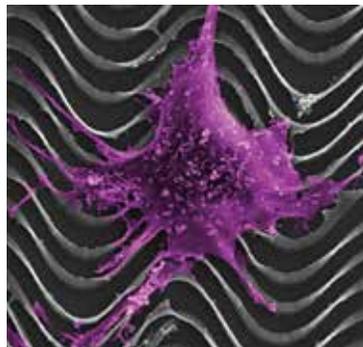
method for screening women at higher risk for the disease. Women with a known BRCA gene mutation—the same mutation implicated in a higher risk for breast cancer—have a 40-percent

chance of developing ovarian cancer in their lifetime. “Those are the women we really want to follow,” says Campagnola. “You could imagine—we’re a long way off from this—screening those women every few years with a minimally invasive device through a laparoscope or through the fallopian tubes.”

But to get to that point, Campagnola says, researchers need to know a lot more about how ovarian cancer works. “You have to know what you’re looking for,” he says. “That’s why we have all this more

basic work to do to get to that point. That’s why we need better imaging tools and we need better models to understand the biology of the disease.”

A \$2 million grant from the National Institutes of Health (NIH) is funding the research.



More: www.engr.wisc.edu/nih-ovarian-cancer-paul-campagnola/

LONGTIME ENGINEERING DEAN PAUL S. PEERCY PASSES AWAY



As dean of the college, Paul Percy constantly sought ways to help students succeed in engineering. In ongoing efforts to educate “global” engineers, he focused on diverse and interdisciplinary experiences, innovations in teaching engineering, and on hands-on work that connected the technical aspects of engineering students’ education with real challenges facing society.

“Engineering is where science meets society,” he said in a 2012 interview, referring to myriad global challenges, including energy needs and pollution. “These are problems that can’t be solved without engineers and can’t be solved by engineers alone.”

Percy, who served as dean from 1999 until his retirement 2013, died October 20, 2016. He was 75.

He came to UW-Madison after having served as president of the not-for-profit consortium of semiconductor equipment manufacturers then known as SEMI/Sematech. He spent 27 years at Sandia National Laboratories in New Mexico, where he rose from the technical staff to director of microelectronics and photonics, a role in which he guided semiconductor development at three national labs.

Percy was known for his focus on engineering education. At the national level, he served on the executive committee and as chairman of the American Society for Engineering Education engineering deans council and remained active with the group after his retirement. Within the College of Engineering, he implemented several initiatives—including those that expanded teaching innovation, exposed students to global challenges, and encouraged cross-disciplinary experience—aimed at preparing graduates to thrive in a rapidly changing international economy.

“Dean Percy cared deeply about the College of Engineering and the preparation the college provides practicing engineers of the future,” says Steven Cramer, the vice provost for teaching and learning at UW-Madison who served as a College of Engineering associate dean under Percy. “He created, moved and accelerated the college on a path of educational innovation long before it was a formal effort on campus.”

Additionally, Percy was deeply committed to efforts designed to help students succeed in engineering. For example, shortly after he became dean, he founded the engineering Undergraduate Learning Center to support students enrolled

in challenging foundational engineering courses. The center has expanded over the past decade and a half to offer studying, training and tutoring support for hundreds of students in more than 50 engineering, math and science courses.

To further encourage undergraduate student excellence, Percy and his wife, Cathy, established the Dean Emeritus Paul S. and Catherine B. Percy Undergraduate Tutoring Fund, which funds an annual scholarship of approximately \$5,000 for an outstanding tutor in the Undergraduate Learning Center.

“Paul’s dedication to engineering students was truly inspiring,” says Ian Robertson, who became College of Engineering dean after Percy retired in 2013. “He led a transformation in the way we approach all facets of our students’ education—and his efforts not only established the college as a national leader in engineering education, but also benefited thousands of past and current students.”

Percy also instituted initiatives to elevate the College of Engineering research profile—among them, efforts to gain federal funding in basic and applied research areas such as materials science, applied physics and microelectronics. He continued the college commitment to building the Department of Biomedical Engineering, which was established in 1999. “These were natural areas of interest for him, given his longstanding research accomplishments and expertise at Sandia and SEMI/Sematech, to make engineering advances science-based,” says Michael Corradini, the Wisconsin Distinguished Professor of Engineering Physics who served as associate dean for engineering academic affairs under Percy. “He had a unique ability to analyze complex issues, identify potential solutions, and efficiently address them to the betterment of the students and the college.”

You can make gifts
in Percy’s memory to the
**Emeritus Dean Paul S.
and Catherine B. Percy
Undergraduate Tutoring Fund**
(fund No. 132340003).

Go to the UW Foundation secure giving
website, secure.supportuw.org/give,
and put the full fund name (above)
into the box under “Choose
what to support.”

GLASS HALF FULL

Improving the world's water

The eel-like parasitic sea lamprey is essentially an ancient Homeric sea monster brought to life, but in miniature. “They’re scary and pretty gross,” says Christy Remucal, an assistant professor of civil and environmental engineering.



The gross-out factor revolves around the lamprey’s mouth: It lacks a jaw, instead possessing a suction-cup-like mouth filled with rings of sharp, thorny teeth that surround a razor sharp tongue. The grotesque mouth is perfectly engineered for the sea lamprey’s parasitic existence: The sharp teeth maintain a firm grasp on the body of host fish while the razor tongue slices the host’s flesh. Voila! The lamprey has a constant source of nourishment—that is, until the host fish dies. Upon the host’s death, the sea lamprey simply detaches and finds another host.

Sea lampreys are a sort of physical manifestation of the general scourge of invasive species—plants and creatures that infest ecosystems and wreak havoc by outcompeting or killing native species and destroying habitats. The sea lamprey is native to the North Atlantic, and—similar to salmon—it’s a versatile fish, capable of thriving in both fresh and sea water. That capability has allowed sea lampreys to invade inland freshwaters, including the Great Lakes, where they’ve preyed on native and game fish, including trout and salmon, for decades.

A joint U.S.-Canadian effort has been fighting back against the invasive sea lampreys for nearly as long as they’ve called the Great Lakes a second home. The method is surprising: Every year, fish and wildlife personnel apply two pesticides—known as lampricides—in some of the 400 Great Lakes tributaries from Quebec to Wisconsin where the sea lampreys spawn.

One of the two lampricides used, a chemical compound called 3-trifluoromethyl-4-nitrophenol—TFM for short—is remarkably effective in targeting sea lampreys in their larval stage while avoiding ill effects on other species. The other lampricide—niclosamide—is less selective, yet is considered safe for widespread use. Still, both TFM and, to a greater extent, niclosamide have been shown to have negative effects on other fauna, and researchers haven’t known much about how the chemical compounds degrade and transform in aquatic environments. That’s where Remucal comes in.

Remucal’s lab, housed in the Water Science and Engineering Laboratory on Lake Mendota, studies the two lampricides and how sunlight breaks them down into other chemical compounds, called transformation products. The goal is to determine how long the lampricides persist in tributaries, and how their exposure to sunlight in aquatic ecosystems may affect aquatic life.

It’s all part of Remucal’s greater focus on the fundamentals of water chemistry and how tiny dissolved contaminants can affect water quality. Remucal also studies ways to remove organic contaminants from water. “These organic contaminants could be everything from pesticides to pharmaceuticals to personal products, such as caffeine,” Remucal says.

And our surface freshwaters are teeming with these contaminants. “For example, we study how sunlight causes chemicals to break down in a lake,” Remucal says.

With more than 15,000 lakes in Wisconsin (not to mention Lakes Michigan and Superior), Remucal and her students have plenty of potential field sites from which to choose. The sheer number of freshwater lakes in the state also demonstrates the importance of Remucal’s work—organic contaminants are present in even the most pristine bodies of water, and it behooves us to better understand how natural processes affect and alter them.

Remucal also conducts research that has very real consequences for public utility operators, who are coming under increasing security after drinking water crises like the recent lead contamination in Flint, Michigan. Remucal doesn’t study lead contamination, but there are many chemicals that could spoil a municipal drinking water system.

“Our current drinking water treatment is really good at getting rid of particles and pathogens that can make you sick, like *E. coli*,” says Remucal. “But the treatment processes aren’t very good at getting rid of many of these organic contaminants.”

So she and her students are studying advanced ways to do just that. Right now, they’re investigating the potential of a treatment system called chlorine photolysis. In a way, it’s related to her research on lampricides and other organic contaminants in surface waters. That’s because the treatment works by combining the chemical chlorine with the power of light, which transforms it into a sort of super disinfectant.

“If you shine light on chlorine, it produces a bunch of radicals,” Remucal says. “These are really powerful oxidants that can break down chemicals that we want to get rid of.”

The basic idea of Remucal’s chlorine photolysis project is to see if utility operators could simply add light to their chlorine disinfection unit, transforming it into an advanced oxidation—and advanced disinfection—process. The process could be useful in safeguarding drinking water from chemical spills or toxic algae blooms, Remucal says.

“This could either be a way to upgrade existing infrastructure or to deal with occasional problems where you need to improve what you’re doing to treat the drinking water,” Remucal says.

And though the application of chlorine photolysis research is promising, Remucal is focused on the fundamental chemistry of the process. Other engineers specialize in designing treatment systems that include the process.

Remucal is one of many researchers on campus whose primary concern is water. UW-Madison historically is well known for its water-related research: The university’s Center for Limnology is considered the birthplace of inland water research in North America, and Lake Mendota is often called the most studied lake in the world. But the true depth (forgive the pun) and breadth of the research conducted at UW-Madison on this most important element for life goes far beyond the study of lakes.

Reflecting the ubiquity of water in our lives, the diversity of water research here is impressive, and much of that research occurs in the College of Engineering. From advanced computer modeling to old-fashioned fieldwork, engineers use a diverse set of scientific methods and tools in their efforts to improve the human relationship



Christy Remucal

Water research faculty

Water research is a collaborative endeavor. Remucal and Block are among many water researchers in several departments, schools and colleges at UW-Madison. These faculty are among those conducting water research in the College of Engineering.

DANIEL WRIGHT is an assistant professor of civil and environmental engineering. Like Paul Block, a lot of Wright's research takes place on computers.



He uses sophisticated computer algorithms to understand long-term flood risks in specific locales or watersheds. He uses remote sensing data—from satellites and ground-based weather radar—and historical observations of river flows in his effort to understand flooding risks over very long periods of time.

"I say 'long time horizon' to contrast it with what we would call in the business 'short-term forecasting,' where when you check the weather and it's giving some projection over the next couple days what might happen," Wright says. "I don't really do that."

What Wright does is more useful to municipal planners and insurers.

"An insurance company would be interested in the sort of thing I do because they are issuing insurance plans that are sort of based on long time horizons," Wright says. "But an even longer time horizon would be infrastructure design. So if we build a bridge, how much do we need to worry about the damage that it might suffer. What are the possible flood scenarios that it might have to withstand over its lifetime?"

Paul Block's research takes him from hydroelectric dams in South America to the famine-prone fields of Ethiopia. Block, an assistant professor of civil and environmental engineering, spends a lot of time considering the water systems (both natural and those altered and harnessed by humans) that affect these regions and others. "My research is focused on a broader view, or what we often call a systems view," says Block. "Instead of some individual component, we will look at how if something in our system changes, how does that perturb other aspects within the system."

This broader view is essential when considering the climate—a hugely complex system that affects just about everything else on Earth. While Block and his research group don't necessarily think on the global scale, their systems approach is crucial for answering questions on the watershed scale.

These questions will become increasingly important as climate change affects agricultural regions and water supply systems. And the questions will often have significant economic and geopolitical consequences.

"If you extract water farther up within a basin—say if you irrigate some fields or some farms—what does that mean downstream?" Block poses. "You obviously have less water, but how does that water balance carry out? Does somebody have less water, or are you storing some water somewhere?"

These questions might seem mundane to those of us who are accustomed to what seems like a limitless supply of cheap, fresh water—but they are hugely important questions in more arid areas of the world, where states and nations squabble over water resources and reservoir operators must deal with the uncertainty of fickle weather patterns and a changing climate.

In his systems-focused work, Block attempts to reduce the uncertainty for reservoir operators and farmers by combining various models—climate, rainfall runoff—to come up with seasonal forecasts that can help water resource decision makers. "If you're a farmer or you're a reservoir operator, and you had some sense of whether summer is going to be wet or dry in advance, would you make a different decision?" Block asks.





Paul Block (right) with postdoc Solomon Tassew Erkyihun

Old-fashioned water resources management depends on averages to make decisions. It's a risky method that can lead to crises in years of weather extremes.

"We're used to saying we know what's happened for the last 50 years, so we take the average of that and we say, 'Well, we don't know anything better, let's use it,'" Block says. "But that's pretty inefficient, and it's hardly ever an average year."

That's increasingly becoming the case as climate change leads to less and less dependable rainfall "averages." Consider southern Louisiana, which experienced devastating flooding in summer 2016—that was the result of rainfall so outside of the average that it was considered a 1 in 1,000-year event. And many locales are experiencing similar 500-year or 1,000-year floods at a much more frequent rate than every 500 or 1,000 years.

So Block and his colleagues are using systems modeling methods to attempt to more accurately forecast climate conditions for risk-prone regions where crops and potable water are at stake.

One region where these forecasts inform water resource decisions is in the arid portions of Peru and Chile, where reservoir operators need reliable forecasts of stream flow to assist in their allocation of water rights within the region. Another

GREG HARRINGTON

is a professor of civil and environmental engineering. Harrington's research has evolved over the years, but he's currently working on drinking water systems. He's interested in the treatment and distribution—how water gets stored and piped to homes and businesses from treatment facilities—of water.



Most of Harrington's research career until the last several years has focused on water quality. "I arrived at UW-Madison three years after Milwaukee had a big cryptosporidium outbreak," Harrington says.

In 1993, Milwaukee dealt with the worst recorded outbreak of the deadly parasite in North American history; 400,000 people became ill in a two-week period, and nearly 100 people died from the contaminated water. "That was the big headline in the newspapers across the country like Flint, Michigan, was recently," Harrington says. "So I arrived here in 1996, and we spent probably the next 12 years studying pathogen removal in drinking water systems."

Most of Harrington's research since then has been on pathogen removal from water and studying microbial growth in drinking water distribution systems. But recently, he's gotten interested in how public utilities can save energy, and money, by optimizing their distribution systems. "I think what's not well known is that drinking water and waste systems are one of the largest electricity consumers in the nation," Harrington says.

Energy is generally the largest or second largest expense for drinking water systems (the other being employees). That's because it takes a lot of energy to move huge quantities of water around. "Madison, on average, pumps something on the order of 25 to 30 million gallons a day," Harrington says. "That's just drinking water."

That's nearly 210 million pounds of water being moved in Madison every day.

Harrington and his colleagues are interested in the pumping systems and understanding how they can make them operate more efficiently.

TRINA MCMAHON

is a professor of civil and environmental engineering. She studies how microbes live together and function in lakes and “activated sludge” (i.e. aerated sewage). Ultimately, McMahon is interested in improving researchers’ ability to predict and model microbial behavior, and how microbial processes could be harnessed to assist engineers.

McMahon uses sensor data and sampling to understand the microbial communities living in freshwater lakes. She’s particularly focused on the cycles of several different nutrients—phosphorus, nitrogen and carbon—in our lakes, and how those cycles are related to water quality and eutrophication (excessive richness of nutrients that can lead to algae blooms and other unwanted effects). She wants to know how specific lines of bacteria contribute to these different nutrient cycles.



MATTHEW

GINDER-VOGEL is an assistant professor of civil and environmental engineering. Ginder-Vogel leads the environmental biogeochemistry group at UW-Madison. He and his students study the biogeochemical processes that control how nutrients and environmental contaminants enter and cycle through the environment.

One contaminant Ginder-Vogel and his group research is radium. The toxic element is common in groundwater around the Midwest—including many towns and cities in Wisconsin—at levels that are near or sometimes exceed the EPA’s maximum contaminant level. To deal with the issue, municipalities have had to make costly adjustments to their drinking water systems, sometimes having to completely abandon old wells and construct new wells. There are also treatment systems that can reduce the radium to levels below the EPA limit. But researchers still know little about how radium actually gets into the groundwater, and Ginder-Vogel’s team is studying the relationship between sediment and the overall geochemistry of groundwater and the concentration of radium in that groundwater.



area is in Ethiopia, where Block uses modeling to assist in precipitation predictions. “The idea there is to say if it’s going to be wetter or drier, these farmers may want to plant something different or they may want to use a drought-resistant seed if it’s going to be dry,” Block says.

And these are high stakes for the mostly subsistence farmers who depend on increasingly erratic rainfall to support their crops. “But they also want to know if it’s going to be wetter,” Block explains. “Because they wouldn’t want to pay the premium for the drought-resistant seed then, and maybe then they’ll use fertilizer because you’ll get your return on that.”

Block says the decisions are somewhat constrained by cultural considerations, like the need to grow teff every year, which is the primary ingredient in injera, a flatbread ubiquitous in the region. That means their models must incorporate social science as well—systems research must include all these considerations.

“But if it’s going to be dry, we ask, ‘Can we assist in suggesting what might be good cropping strategies?’ says Block. “So we also have an agriculture economic model that we’re feeding this info into. What if X percent of farmers adopt this policy; what does this mean for, in this case, poverty? What does this mean for agriculture and GDP? There’s a whole adoption piece of this, which is in the social science realm. Why do these farmers make the decisions they make, or why do they choose to ignore forecasts?”

So Block has teamed up with a group of ethnographers living in the villages he’s working with. “They’re really trying to understand the decision-making processes, and how this information—in our case particularly related to forecasts—is passed to farmers,” he says. “How are they receiving this, or not? Are they taking action based on this, or not?”

In the case that the farmers do not heed the forecasts, Block says the team’s goal is then to figure out what it can do to increase uptake. Do the researchers



Paul Block (left) and Solomon Tassew Erkyihun

Christy Remucal



need to improve the forecasts? Or do they simply need to tailor the forecasts to be more specific? Or perhaps it's a governance or communication issue; the forecasts are fine, but they aren't reaching the right audiences. The ultimate goal is to encourage more farmers to plan ahead with the use of the forecasts, which can be difficult when the forecasts aren't perfect.

"So one year we say, 'Oh, it's going to be real wet,' but it turns out to be dry. There's a lot of noise in the climate system, so there will be years when the predictions are not correct," Block says. "So what happens then? Do we lose trust? Do farmers not rely on the forecasts anymore? What are those dynamics?"

The task is to link this cognitive aspect that might limit adoption to the technical and economic forecast to ultimately encourage adoption. "So really we're moving beyond just engineering," Block says.

The National Science Foundation has started referring to this new type of trans- or interdisciplinary research as "convergence." "It's a nice way to describe what we're doing," says Block. "We team with climate scientists and social scientists, and we all have to kind of converge to an extent both in the understanding of each other's fields, but also converge to a point where we may be able to offer something of value collectively, in this case to farmers. Can we do that or not?"

Block's project in Ethiopia is planned for five years and just beginning. The ultimate goal is to refine the models and build a mobile app that uses the forecast data to assist farmers in their decisions. "It's really exciting for me," says Block. "It's the same thing with the reservoir operator: These farmers are optimizing a lot of different things. And this is hopefully one piece of information that we can provide."



STEVE LOHEIDE is an associate professor of civil and environmental engineering. Loheide leads the eco-hydrology and ecosystem engineering research group at UW-Madison. The group is interested in how water moves through the environment as it interacts with the complex and changing needs of humans, including municipal and industrial uses, agriculture and natural ecosystems.



The group is particularly interested in how science and engineering can assist in ecosystem restoration, particularly the restoration of rivers, streams and wetlands.

CHIN WU is a professor of civil and environmental engineering. Wu leads the environmental fluid mechanics and coastal sustainability lab. Wu is interested in water quality and the nutrient cycles that affect it, and he also studies the physical processes involved in air-sea interactions.



Wu and his research group are specifically interested in how waves break along a shoreline and how wave-current interactions affect those wave breaks. The research involves both lab and field work to assess how a combination of factors, including humidity, head and momentum, affect waves, as well as how they can create so-called "freaky waves": large waves that seem to come out of nowhere. The research will hopefully help scientists be better able to predict waves in an evolving climate scenario.

Waves—and currents and water turbulence—also affect how all sorts of material is deposited on lake, sea and riverbeds. This material includes everything from sediment to organic contaminants. Wu is interested in how organic contaminants and other pollutants cycle through aquatic systems and how they can affect public health and safety. Again, Wu uses lab and field techniques, as well as modeling, to understand how coastal erosion and other hydrologic processes affect everything from algae blooms to sedimentation of rivers and wetlands.

WIRELESS HOTSPOT HERE

UW-MADISON RESEARCHERS
ARE FAST BECOMING LEADERS
IN TECHNOLOGY TO ENABLE AN
INCREASINGLY INTERCONNECTED
WORLD





There are more devices on earth capable of connecting to the Internet than there are people living on the planet.

Phones in people’s pockets, wearable technologies on their wrists, smart devices in their homes, and self-driving cars all tap into wireless networks. Those networks exchange more than 3.7 exabytes (or 10^{18} bytes; one byte is roughly equal to a single character) of information every month, which is equivalent to 80 percent of the data volume of the entire Internet, or enough digital material to fill up five and a half billion compact discs.

That staggering volume of information puts tremendous strain on wireless networks—and the modern world’s invisible infrastructure is long overdue for an update.

“The need for advances in wireless communication and mobile systems is stronger than ever before, especially as users continue to expect anytime, anywhere access through their personal devices,” says Suman Banerjee, a professor of computer sciences and electrical and computer engineering and head of the Wisconsin Wireless Networking Systems Laboratory.



Sayeed



Zhang



Banerjee

But slower-than-molasses data-rates aren’t just an annoyance for 90,000 fans trying to post photos to social media at a sporting event, or even people simply out running errands; an overloaded network could prevent some important emerging technologies from ever seeing the light of day.

“There are a lot of new innovations such as smart cities, autonomous vehicles, and the Internet of Things, which are resting on the premise of fast access to cloud computing and the cloud being everywhere,” says Akbar Sayeed, a professor of electrical and computer engineering who leads the Wireless Communications and Sensing Laboratory.

Sayeed is among many UW-Madison researchers who are developing transformational technologies that rely on wireless to tap into the cloud—the data stored and accessed anywhere through a wireless connection.

For example, students working in the Internet of Things Lab at UW-Madison design smart devices such as wearable monitors that can contact emergency medical professionals if a patient’s vital signs vary from healthy values. In 2015, a system of wireless sensors that ensures people use proper form during strength-training exercises moved beyond the lab and into the UW-Oshkosh football team’s weight rooms for field-testing under the auspices of WeightUp, a startup company co-founded by UW-Madison electrical and computer engineering graduate student Pete Chulick.

Smart devices also are coming online in developing nations. Electrical & Computer Engineering Professor Giri Venkataramanan’s research group is working to develop small-scale electricity distribution systems called microgrids that empower rural communities to take ownership of their own energy generation. The circuit boards that manage microgrids come with wireless

connectivity, meaning that people can text-message their homes to activate cooling systems or monitor energy consumption from afar. Thanks to a partnership with the startup company NovoMoto, founded by engineering mechanics PhD students Aaron Olson and Mehrdad

Arjmand, several prototype microgrids are already up and running in the Democratic Republic of the Congo.

Right now third-generation (3G) wireless networks cover most industrialized nations, and fourth-generation (4G) systems are becoming increasingly common. Those 4G networks are considerably faster, but engineers are already looking ahead to bring about the next generation: 5G. When the fifth generation of wireless does come online, the speediest 4G systems will seem glacially slow by comparison. “We can imagine that a 5G wireless Internet connection will be as fast as a wired connection. Cellular connections will be as fast as ethernet cables and a lot of devices will be connected to the 5G network,” says Electrical and Computer Engineering Assistant Professor Xinyu Zhang.

According to standards set by the International Telecommunications Union (ITU), 5G wireless will achieve



gigabit-per-second data rates for multiple users in the same area. In other words, no more foot-tapping while you wait for a page to open in your phone's Internet browser: Imagine sending or receiving the complete works of William Shakespeare—20 times—in a single second. That's a gigabit. In more modern terms, a 5G connection would enable you to download an entire episode of a 30-minute high-definition television show in less than 30 seconds.

Reaching the fifth generation won't be easy. Each of the preceding generations built on progress that didn't require fundamental changes to the wireless infrastructure.

The first generation of wireless cell phones, for example, made calls using analog modulations of radio signals on 1980s-era phones like the Motorola Dyna-MAX8000 that stood as tall as bricks, and weighed nearly twice as much.

Finland launched the world's first second-generation (2G) network in 1991. The first to convert voice calls to digital information, it paved the way for modern data messaging. In fact, just one year later, in 1992, a Canadian engineer sent the world's first text message, which read, "Merry Christmas." Now, Americans send more than six billion text messages every single day.

Although some industrialized nations, like the United States, Singapore and Switzerland, have announced plans to eliminate second-generation networks by 2017, many people in the developing world still use 2G. However, because the systems operate far below the 200 kilobits-per-second data rates that define 3G, browsing the Internet on a 2G connection can be painfully slow.

Third-generation wireless (3G) delivered the necessary performance to surf the web from mobile devices, but the initial roll-out was slow after debuting in Japan in 2001. When smartphones hit the market, however, more people started demanding mobile broadband and now 3G covers 84 percent of the world's population.

The ITU established standards for 4G systems in 2008, but eased back on those initial requirements in 2010. Even though the Long Term Evolution (LTE) and WiMAX networks coming online in the United States and Asia often fall short of 100 megabits per second mobile data rates that define true 4G, these systems use different frequency bands and deliver substantial performance improvements.

"In the first four generations, people relied a lot on improving communication hardware and signal processing algorithms, but that aspect has reached an upper limit," says Zhang.

He predicts that 5G will use more disruptive technologies—for example, millimeter wave.

And without those disruptive technologies, there simply won't be enough bandwidth to go around. The Federal Communications Commission has strict rules in place to divvy up radio frequencies, which is a good thing because crossing frequencies among different applications would be disastrous. Pilots communicating with air traffic control towers use different frequencies of radio waves than pop music stations, for example.

Waves on the electromagnetic spectrum can be described by the distances between their crests. These wavelengths can range from smaller than atoms, like gamma rays, or miles long, like time signals that set radio clocks.

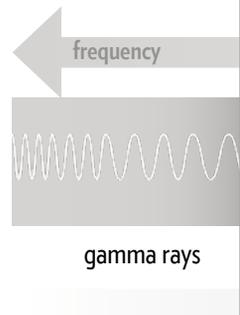
Because all electromagnetic waves travel at the speed of light, huge numbers of radio waves vibrate past a given point in one single second, and the frequency of those waves increases as the wavelength gets smaller. Tiny ultra-high-energy gamma rays cycle more than 10 billion-billion times per second (a whopping 10 exahertz), whereas ultra-low frequency waves that vibrate a mere 50 times per second span more than three miles in length (1 cycle per second equals one Hertz). AM radio broadcasts use waves about 450 yards long. They oscillate 10 million times per second, or 1 megahertz. Over-the-air television broadcasts occupy frequencies around 800 megahertz, corresponding to a wavelength of about the distance traveled during one average walking step.

Currently, mobile wireless receives a few frequency bands in the neighborhood of 1.7 and 1.9 gigahertz, which means those waves range from about 2.5 to 6 inches—about the length and width of a dollar bill.

But even space for electromagnetic waves is limited, and some bands are filling up fast. "Existing wireless networks operating below 6 gigahertz simply do not have enough spectrum to sustain the current growth and deliver the expected data rates," says Sayeed.

Fundamental theories dictate that the speed of a wireless network is directly proportional to the amount of available bandwidth—the distance between the lowest and highest frequencies in a given range. Bandwidth does not come cheap. A typical 4G cellular tower uses around 100 megahertz of spectrum to cover everybody in the area, and that 100 megahertz usually costs billions of dollars.

Imagine sending or receiving the complete works of William Shakespeare—20 times—in a single second. That's a gigabit. In more modern terms, a 5G connection would enable you to download an entire episode of a 30-minute high-definition television show in less than 30 seconds.





Ongoing research at UW-Madison is turning the Badger State into something of a wireless research hotspot.

“There’s a critical mass coming together in Wisconsin, even though we’re far away from Silicon Valley or Telecom Valley,”

–Akbar Sayeed–

In July 2016, the U.S. Federal Communications Commission made waves in the wireless community by freeing up a whopping 11 gigahertz (one gigahertz is 1,000 megahertz) worth of spectrum specifically for 5G and mobile broadband. Two days later, the National Science Foundation announced a seven-year, \$400 million initiative to make 5G a reality.

But taking advantage of those newly available regions of spectrum won’t be as easy as switching stations on a car radio. The majority fall in very high frequency ranges—above 24 GHz—which is in the millimeter wave range of the spectrum. Unlike the longer, lower frequency waves used now, millimeter waves can’t pass through many obstacles such as walls or human bodies.

That requirement for an unobstructed path is among myriad challenges for 5G wireless. But ongoing research at UW-Madison is turning the Badger State into something of a wireless research hotspot. “There’s a critical mass coming together in Wisconsin, even though we’re far away from Silicon Valley or Telecom Valley,” says Sayeed.

Wisconsin engineers are not only developing new hardware and software, but also setting up testbeds to help bridge the gap between laboratory prototypes and market-ready products.

In fact, Zhang’s laboratory was one of the first places to ever send streaming video over 60 GHz millimeter waves on a platform called WiMi. Using that testbed, Zhang’s group figured out a potential solution to obstructions in millimeter wave travel: Reflect the signal beam off a solid nearby object and steer around the obstacle.

WiMi is but one of many tools on campus through which researchers can tinker with new hardware and software schemes for 5G wireless. Another testbed led by Sayeed is designed to devise strategies for maintaining connections with multiple moving users using state-of-the-art multi-input/multi-output

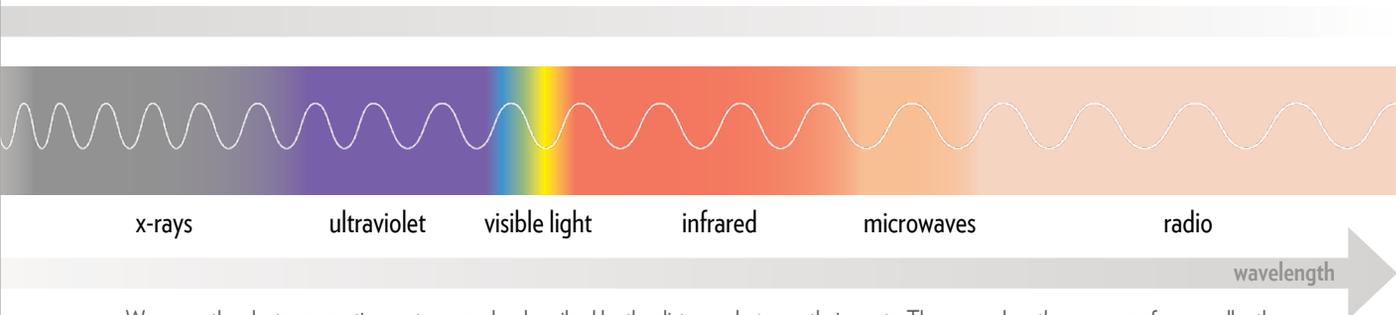
antennas that use multiple beams for communications. This testbed is based on a patented wireless technology called CAP-MIMO, pioneered by Sayeed’s group, that is also being developed for potential commercialization in emerging millimeter-wave 5G applications.

And newly renovated lab spaces on the third floor of Engineering Hall, updated thanks to a generous gift from ECE alumnus Peter Schneider (BSEE ’61, MSEE ’63 PhDEE ’66), are already starting to buzz with activity.

“These new labs (in combination with the remodeling of the Plexus Collaboratory and the Qualcomm design labs) are a fantastic asset for the department’s research in mobile systems,” says Electrical and Computer Engineering Professor Parmesh Ramanathan, who researches advanced computational algorithms capable of processing millimeter wave signals into useful information.

The research isn’t only confined to labs on campus; citizens in Madison have been field-testing advanced wireless systems ever since 2010, when two Madison Metro buses began connecting passengers to high-speed internet, thanks to a project called WiRover, led by Banerjee. Now Banerjee is setting the wheels in motion on a new initiative, named WiNest, that promises to turn the entire city of Madison into a testbed for advanced wireless and mobile systems.

Sayeed and Zhang also are heading a research coordination network in the area of millimeter-wave wireless to foster collaboration among industry developers, academic scientists, policymakers, and federal stakeholders as these normally disparate groups all start exploring the bold new frontiers of 5G wireless. “This is a really exciting time,” says Sayeed. “5G will be a clean slate because it is so different. The basic science and the engineering are not well understood, and neither is the technology. Here at UW-Madison we’re pushing forward on all fronts.”



Waves on the electromagnetic spectrum can be described by the distances between their crests. These wavelengths can range from smaller than atoms, like gamma rays, or miles long, like time signals that set radio clocks. Currently, mobile wireless receives a few frequency bands in the neighborhood of 1.7 and 1.9 gigahertz, which means those waves range from about 2.5 to 6 inches—about the length and width of a dollar bill.

PRESTIGIOUS FELLOWSHIP PAYS TRIBUTE TO TRIO, HONORS TALENTED CBE GRAD STUDENTS



Bird



Stewart



Lightfoot

Fellowships provide graduate students with critical financial support as they pursue advanced degrees. In the case of the **Bird Stewart Lightfoot (BSL) Wisconsin Distinguished Fellowship**, a fund established as a permanent endowment for graduate students, those students are linked to three of the most prestigious names in the field of chemical engineering. R. Byron (Bob) Bird, Warren Stewart and Edwin Lightfoot are co-authors of the landmark textbook *Transport Phenomena*, and individually are research giants—but they also have made significant contributions in teaching and service.

The chemical and biological engineering department provides fellowships, such as the BSL, that support graduate students throughout their first semester, at the end of which they join a faculty member's lab group and receive funding through that person's research grants.

For many students, including alumnus Jeffrey Herron, who received the BSL Fellowship in fall 2008, having financial support in the first few daunting months of graduate school is crucial. "Because I had funding for a year from the department, I had time to explore what options were available, meet with faculty and their students, and see what kind of work I would be taking on," he says. "Having that time, and not going in blind, helped me make a better decision for my research interests. Having that flexibility in funding is important in having a successful graduate career."

Herron, currently a senior engineer at Dow Chemical Co. in Midland, Michigan, is one of 10 students who received the fellowship since the department began



offering it in 2007. Ultimately, Herron went on to join Manos Mavrikakis' group, specifically applying quantum chemical calculations to the identification of new materials, focusing on applications in energy. In his work with Dow, he helps scale up lab reactions to commercial-scale, often applying similar tools and calculations that he worked on during his graduate research.

For current graduate students Nat Eagan and Maddie Ball, who both received the fellowship in spring 2015, the financial support helped them expand their knowledge of their respective fields. "It gave me the opportunity to get out of the door and see things that I wasn't necessarily at the stage to be a part of yet," Eagan says. "I was able to go to the American Institute of Chemical Engineering conference in Salt Lake City, Utah. I gained a lot of good experience just being there."

"Having a fellowship means that I'm not tied to a particular project, so I can work on things that are of interest to me and my advisor."—Maddie Ball

Ball, a student in Ernie Micek Distinguished Chair Jim Dumesic's lab, was able to use the extra funds to travel to the University of New Mexico, where she worked with some of the group's collaborators on electron microscopy. "Getting to work with them, and seeing what they do in the field of catalysis, helped me advance that area of my research," says Ball.

The BSL Fellowship also gives students some latitude in their research. "Having a fellowship means that I'm not tied to a particular project, so I can work on things that are of interest to me and my advisor," says Ball. "In terms of my research, we can do things that are a little more exploratory."



Maddie Ball



Nat Eagan

She continues to conduct research in controlled surface reactions, in reference to the synthesis and characterization of bimetallic catalysts. Ball, who enjoyed the experience of working as a teaching assistant, is excited about the idea of pursuing a faculty position in the future.

The BSL Fellowship also helps validate students' perceptions of their academic path. "Bird, Stewart and Lightfoot were some of the most well-known names to come out of the university, with a lot of theories fundamental to the understanding of transport phenomena," Eagan says. "So having my name attached to the fellowship makes the most difference. It tells me that I'm on the right track, and doing the right things."

For Eagan, the fellowship means much more than funding for his graduate education. It's a signal that he and other recipients have potential, an encouragement in the trying early phases of an academic career. He now is a member of Professor George Huber's group.

The BSL Fellowship is among several fellowships that help the Department of Chemical and Biological Engineering to remain competitive, enabling it to attract some of the most academically advanced students. Not only does it illustrate the success of the department, it also provides students with the motivation to embrace their research.

Manos Mavrikakis, Vilas Distinguished Achievement Professor and Paul A. Elfers Professor and department chair, highlights the importance of the fellowship, not merely because of the endowment it provides, but in what it signifies. "Bird, Stewart and Lightfoot are three of the most recognizable names in the history of chemical engineering on the global scale," he says. "Having a graduate fellowship with that name is among the highest honors a chemical engineering graduate student can ever imagine."



IT'S CLEAR AS A BELL

Ingenuity enables BME senior to complete 'unimpossible' mission

It's hard to take Chris Nguyen seriously when he says, "I'm just a regular guy." After all, the senior biomedical engineering student drew leaders from international industrial giant GE to campus in early September, bearing awards and scholarship money.

Nguyen, a Waukesha, Wisconsin, native, won GE's "Unimpossible Missions: The University Edition" contest, by designing a way to prove a popular idiom ("You can't un-ring a bell," in his case) wrong using the company's technology.



On top of a scholarship of up to \$100,000, Nguyen's win secured a 10-week internship in 2017 at the Global Research Center in Niskayuna, New York—the 116-year-old facility where GE engineers created equipment for the first radio and television broadcasts.

He visited in summer 2016 to tour and talk through his Unimpossible Mission entry, and came away awed by the breadth



of technology GE researchers work on, and the boundaries they get to push. "While I was there, I met an engineer from Madison working on tiny robots that go into jet engines and fix them, so you don't have to take the engine apart," he says. "Now I'm thinking about miniaturized electronics, maybe for healthcare. But I'm open to anything, and working on any project at GRC would be amazing."

For the Unimpossible Mission contest, Nguyen theorized that he could use foam to isolate the ringing of a one-ton bell and eliminate unwanted echo. From there, he proposed using a microphone and GE's subsea acoustics system to analyze the exact frequency and amplitude of the bell, then produce the exact same sound in inverse phase—thereby creating destructive interference. The interfering sound would play over speakers, resulting in noise cancellation of both the bell and the interference, and creating absolute silence.

On top of the work Nguyen has done as a student—including his role on a team that designed a centrifuge that helps return more blood to patients during surgery—he also has spent time as a residence hall house fellow and counselor at Camp Badger, keeping groups of visiting teenagers on task and interested in engineering. "I think all of these skills make Chris a more versatile, well-rounded engineer," says College of Engineering Dean Ian Robertson. "They demonstrate what a remarkable individual he is, and what a valuable asset he is to our college and the UW-Madison community."

More: www.engr.wisc.edu/ge-visits-campus-honor-student-contest-winner-talk-innovation/



UW-MADISON TEAM WINS INNOVATION AWARD IN HYPERLOOP COMPETITION



Elon Musk sits inside the Badgerloop pod at the SpaceX Hyperloop pod competition in Hawthorne, California.



A team of UW–Madison students won an innovation award in a worldwide SpaceX Hyperloop pod competition. The UW–Madison Badgerloop team competed against 30 teams from colleges and universities from around the world in the second phase of SpaceX’s Hyperloop pod competition, which was held Jan. 27-29, 2017, outside SpaceX headquarters in Hawthorne, California.

Teams spent the week leading up to the competition on site at SpaceX, where they put their pods through a litany of tests in hopes of getting the chance to run their pods on SpaceX’s one-mile hyperloop test track.

The brainchild of SpaceX and Tesla Motors co-founder Elon Musk, the Hyperloop is a futuristic high-speed transportation system. The idea is for passengers to travel in levitating vehicles—hyperloop pods—through an above-ground vacuum tube, enabling super-fast travel between distant cities.

After more than a year of intensive design work and construction, the Badgerloop team took its 15-foot-long, 2,100-pound pod to California for the competition. While some bugs in the pod’s mechanical and electrical systems ultimately prevented Badgerloop from making a run on the test track, Badgerloop operations director Claire Holesovsky said the experience of building the pod as a team and

participating in the competition has been very rewarding.

“It’s been an awesome experience, and we’ve learned so much,” Holesovsky says. “We received great feedback from the SpaceX judges and from talking with the other teams. It’s really exciting to be working on technology that has the potential to revolutionize high-speed transportation.”

In the end, only three of the 30 teams in the competition were able to actually launch their pods on the test track, which highlights the extreme difficulty of the technical and engineering challenges the student teams faced as they attempted to design and build pods for an entirely new mode of transportation. When they announced the results of the competition, the SpaceX judges emphasized how difficult it was to build a levitating hyperloop pod that doesn’t crash, adding that they weren’t sure if any of the teams would be able clear all the technical hurdles that would allow them to safely run

THE ACCIDENTAL ENGINEER: PHD STUDENT WORKS TO MAKE DRIVING SAFER

their pod on the track. Delft University of Technology from the Netherlands was the overall winner with the highest score in the competition, and the Technical University of Munich won the award for fastest speed achieved in the hyperloop tube.

Badgerloop received one of two innovation awards in the competition. The judges noted the team's innovative designs, including the virtual reality setup that Badgerloop created.

Badgerloop leaders said it's an honor to win the innovation award, especially since the team is led by undergraduates. "I think it's really exciting to see that something so technologically advanced can be made by a group of undergraduates," says Badgerloop team member Jack McGinty, an electrical engineering and computer science student. "To see freshmen come in and make a significant contribution on developing a 15-foot-long, levitating hyperloop pod has been pretty incredible, and it has made me realize that I can do whatever I push myself to achieve."

The team purposefully built its pod to fit Musk, who is 6 feet 2 inches tall. Badgerloop got its wish when, after delivering remarks at the competition, Musk toured the various teams' booths and took the opportunity to sit in the Badgerloop pod. "We were all ecstatic to see Elon sit in our pod," Holesovsky says. "He checked out our pod's technology. It was a great highlight in an incredible week for the team."

Badgerloop, which won third place in the initial round of SpaceX's Hyperloop pod competition, will continue to work on and refine its pod. The team already has plans to compete in the next installment of the competition, which is set to take place in summer 2017 at SpaceX's hyperloop test track.

"Badgerloop is definitely going to continue, and I can't wait to see what we can accomplish," Holesovsky says.

In her research, industrial and systems engineering PhD student Morgan Price figures out ways to avoid accidents and improve vehicle safety—but when she first "bumped" into engineering, that was one accident she couldn't avoid. "When I stumbled upon it, I didn't realize how few women were in the field," says Price. "Then what surprised me more was being a woman and a person of color. That is uber-rare."

Price wasn't planning on being an engineer herself. However, as she began her undergraduate career at the University of Iowa with a focus on pre-med, the idea of cutting open others as a doctor grew less and less appealing.

That's when things started happening.

On the short list: She connected with the Women in Science and Engineering (WISE) group, which set her up with a mentor in emergency medicine at the University of Iowa Hospital. Price then got a job with the hospital as a research assistant tasked with examining ATV crashes and creating a database of YouTube videos. She earned a spot in the prestigious McNair Scholars program, which helps prepare undergraduate students for doctoral studies through involvement in research and other scholarly activities. She worked with Corrinne Peek-Asa of the Injury Prevention Research Center at the University of Iowa, and also collaborated with Dan McGehee, director of the Human Factors and Vehicle Safety Research Division at the University of Iowa Public Policy Center. She was a research assistant for the University of Iowa Public Policy Center, focused on teen drivers and the geographical locations of accidents and incidents.

After she earned a BS in biomedical engineering, Price travelled to Romania, where she researched pedestrian crashes and their causes. After a summer abroad, she returned to the University of Iowa as a master's student and as a research assistant for both Peek-Asa and McGehee. She worked for a summer at the SAFER Vehicle and Traffic Safety Centre at Chalmers University in Goteberg, Sweden, then returned to Iowa and graduated with a master's degree in injury epidemiology.

While Price completed both her bachelor's and master's degrees at the University of Iowa, she had one big reason to want to switch to UW-Madison for her PhD program.

That was John Lee, the Emerson Electric Quality & Productivity Professor in industrial and systems engineering. "When I decided to pursue a PhD, he was obviously the first option in my mind," says Price. And Lee had already heard about Price and was eager to meet her. Shortly after, Lee invited her to join his lab, and from there, there was no looking back.

Currently, Price works in the Cognitive Systems Lab with Lee, where she is researching how vehicles convey their capability; in other words, how does a car tell the driver when it can and cannot handle a situation? Price hopes to expand that communication between car and driver to outside the vehicle via social interactions. For example, most drivers have stopped for a pedestrian to cross the street. However, that can oftentimes be an unspoken communication through a gesture or other signal. She is researching how to incorporate that form of communication into a self-driving vehicle.

Price expects to graduate by 2019 and fulfill her childhood dream of earning a doctorate. And she knows whatever she does needs to have an impact for future women engineers, and specifically for women of color. "I've always felt like there was a greater purpose to my life than just getting a job and I think that could be my purpose. Going the academic route, and trying to not necessarily break barriers, but just shake things up a bit," says Price. "It doesn't always have to work like this and we can introduce different ideas."



More: www.engr.wisc.edu/accidental-engineer-phd-student-works-make-driving-safer/

Research is often an empowering experience for undergraduates, but for six students in summer 2016, their efforts generated results that could also help bring power to people around the world. The team worked to develop small, self-contained electric power grids, or microgrids, under the guidance of Giri Venkataramanan, a professor of electrical

and computer engineering, and Ashray Manur, a graduate student in Venkataramanan's group.

In the developed world, most people plug in to major metropolitan power grids—hundreds of thousands of homes connected by miles of high-voltage transmission lines drawing power from massive far-off plants.

Although the miniature homes completely lack comfortable furnishings and decor, they do feature LED lights, fans, stereo speakers, and USB outlets to charge personal devices. Most importantly, each cart comes equipped with a circuit-board brain: the microgrid manager that monitors and controls energy use.

Boards like those in the lab have been demonstrated in microgrid pilot installations in the Democratic Republic of the Congo, thanks to a partnership with Madison-based start-up NovoMoto, which was founded by two UW-Madison engineering graduate students.

"NovoMoto evolved as our No. 1 beta-test partner," says Venkataramanan. "They tell us the changes they'd like to see. The larger project is always to make microgrids more field-ready."

And the team of summer students made significant progress on that front in just a few short months.

For example, student Alec Sivit developed algorithms so that users can control the microgrid manager wirelessly using text messages, while Ben Chylla and Sam Sivit developed web and mobile apps to monitor power consumption.

"It came together organically because we had electrical engineers, computer engineers and computer science students working together or in parallel," says Venkataramanan.

More: www.engr.wisc.edu/undergraduate-research-enables-big-steps-forward-small-scale-power-grids/

Working on microgrids requires broad

THANKS TO UNDERGRADS, SMALL-SCALE POWER GRIDS TAKE BIG STEPS FORWARD



And rarely do they consider the mind-boggling amounts of infrastructure and highly sophisticated algorithms that keep the system humming along.

Until the system stops humming.

"Hurricane Wilma [in 2005] made me realize how dependent we are on the grid," says Nicole Bugay, a visiting student from Florida. "We were without power for a week, which sparked my interest in solutions for off-grid renewable energy."

Microgrids empower people to take control of their own electricity generation without the need for massive metropolitan infrastructure. Beyond keeping the lights on in case of emergency, microgrids could bring power to people in remote parts of the world. "A community can come together to buy a diesel generator or solar panel array, even though each home couldn't afford such expensive equipment by itself," says Manur. "But the community needs to control power distribution between and within each house, which is what microgrid technology enables."

Venkataramanan's group has been working for several years to develop the necessary hardware, software and firmware to monitor and control electricity flow for single homes or small communities. In the lab, they test prototypes using small-scale approximations of houses perched on laboratory carts.



SOLAR SOLUTIONS FOR SUB-SAHARAN AFRICA

With their innovative startup company, NovoMoto, engineering mechanics PhD students Aaron Olson (*top*) and Mehrdad Arjmand (*bottom*) aim to replace fuels traditionally used in sub-Saharan Africa with a unique blend of technologies they call MicroPlant.

In particular, they're focusing on nearly 70 million people in the Democratic Republic of the Congo, who spend a quarter to a third of their annual income

on kerosene to meet their lighting needs. Olson and Arjmand hope to provide those people with renewable, sustainable electricity that allows them to, for example, operate LED light bulbs, radios or fans, or to charge a mobile device.

Their affordable alternative to kerosene incorporates solar power technology, microgrids, charging stations, control and monitoring software, mobile money, and local partners to deliver reliable

electricity to Congolese homes.

The company steadily has been gaining attention: In June, NovoMoto won third place and \$20,000 in the U.S. Department of Energy's 2016 Cleantech University Prize National Competition. And in April 2016, NovoMoto won \$90,000 in the Clean Energy Trust Challenge, a startup contest billed as the "largest single-day clean energy pitch competition in the nation."



IT'S MUSIC TO THEIR EARS

For youth with MD, engineering students' system reduces barriers to playing baritone

I

In people with muscular dystrophy, severe muscle weakness can greatly inhibit any form of movement. For Roy Thorson, a 14-year-old from Wausau, Wisconsin, the condition often prevents him from doing the thing he loves most: playing his baritone horn.

When he met Christopher Luzzio, an associate professor of neurology (and ME affiliate), Roy knew how to play the baritone, but was only able to blow through the mouthpiece while one of his parents pressed the keys. Luzzio decided there was no better way to face this problem than present it to mechanical engineering students in his course, ME 601: *Design for Rehabilitation*.

The project involves the use of small buttons to power a pneumatic system, which in turn actuates the keys on the baritone. The students, Luke Steinbach and Zach Vargas, initially struggled to identify a way to connect the slight mobility of Roy's fingers to the instrument itself. They drew on the expertise of Professor Emeritus Frank Fronczak, who advised that they use a pneumatically powered system that makes use of an air compressor.

The students also designed and 3D printed a hand controller—specifically molded to the shape of Roy's hand—with buttons that would be both comfortable and highly convenient. When Roy clicks a certain button on this controller, which is shaped much like a computer mouse, the signal travels through a small hose and actuates the air compressor, which depresses the corresponding valve on the baritone. As a result, Roy can play his instrument independently.

Since devising the system, Steinbach and Vargas have worked with Luzzio on multiple iterations to make it highly efficient. This is not the first individual-based project on which Luzzio and his students—both past and present—have embarked. In previous

classes, his students designed a system that could flip the pages on a Nook for a person with multiple sclerosis with limited hand mobility. Another project involves a device that allows artists with muscle weakness to paint using a joystick to control a brush's movement and stroke types. "I think it's very exciting to identify someone, then build something specifically for them, to improve their quality of life," Luzzio says.

More often than not, these projects present themselves to Luzzio, whose medical practice centers around multiple sclerosis. As a result, he has many patients with both unique and common needs. He makes an effort to serve as many of these needs as possible using engineering solutions, but often, the more interesting and engaging projects are those that put students in contact with an individual, who serves as their client for the semester.

For design classes such as his, which are largely geared toward seniors and graduate students, Luzzio looks for hands-on projects that will allow students to build something, learn something about computer control, and offer multiple levels of interaction, both with him, the client, and each other. As is the case in the workplace, the students draw on any resources available to them and work with each other and their client to determine the best solution for their client's design challenge. And as they've learned, there's not always just one answer, but the outcome generally is rewarding both for students and client.

This project was possible thanks to support from donors Pat and Leroy Fischer, Rita and Jason Keys, and Stuart and Polly Brandes.





NEW HIGH-POWER EVINRUDE OUTBOARD BUILT WITH UW-MADISON SOFTWARE

To understand what happens inside the cylinder of an outboard motor running at 5500 rpm, BRP/Evinrude got some help from an unlikely source: software code originally written to understand the motion of air after an atomic bomb explosion.

The physics of fluid flow are applicable in both cases, says Rolf Reitz (*right*), a professor emeritus of mechanical engineering. In the 1970s, in response to the OPEC oil crisis, Reitz helped repurpose code written by the weapons group at Los Alamos National Laboratory for the auto industry.

The result became the basis for a package called KIVA that predicts and explains the highly complex events inside an engine's cylinder, allowing designers to reach the "sweet spot" of high power, good fuel economy and low emissions.

The cylinder is a complex place, says Paul Westhoff, a mechanical engineer at BRP/Evinrude in Sturtevant, Wisconsin.

Westhoff led the computational fluid dynamic modeling during the "blank sheet of paper" design for the combustion cylinders in Evinrude's E-TEC G2 engines, introduced in 2014.

To take just a few critical variables, designers must balance the location, size and shape of the intake and exhaust ports; the shape of the piston and cylinder head; and the timing and direction of the fuel spray and the spark that ignites the explosion.

These factors combined affect how air enters the cylinder and mixes with the fuel spray, and how the burned gas exhausts after the explosion. Reaching one goal can compromise another, Westhoff explains. "You want to mix fuel and air throughout the cylinder, but don't want fuel going out the exhaust port."

Evinrude's new engines, which range from 200 to 300 horsepower, are two-stroke, direct-injected engines, and represent



Rolf Reitz

the industry's best combination of power, economy and low emissions, Westhoff says.

Because the theoretical mix of designs is essentially uncountable, the traditional method of engine design—reliant as it is on metal prototypes—is expensive, and every modification costs more money. Yet until recently, engine designers had few alternatives.

So when BRP/Evinrude, a venerable Wisconsin manufacturer with 700 employees that is now a division of BRP Inc., embarked on a total redesign of its flagship high-power outboards, it took an entirely different approach: designing with simulation.

The process relied on KIVA, open-source software that has been under steady development at the UW-Madison Engine Research Center.

Reitz began working on software to describe furiously moving fluids for his PhD work at Princeton University in the late 1970s. "The Department of Energy wanted to take the governing equations from Los Alamos research—the physics should be the same—and apply them to engines, and they were very successful," Reitz says.

Eventually, the software principles and expertise developed at UW-Madison spread through the auto industry, and KIVA and related software from private companies has been put to work by Ford, Cummins, Caterpillar and many other big engine makers, Reitz says.

In his long career exploring the complex events inside engines, Reitz has also used KIVA to develop gasoline-diesel hybrid engines that offer some of the highest efficiency in the world.

Westhoff says Evinrude's "blank sheet of paper" design process began where all the action starts: inside the cylinder.

"We modeled fluid flow through the cylinder—the induction of air from the crankcase through the intake port into the cylinder, which displaces the residual exhaust from the previous cycle. It's important to maximize the amount of trapped oxygen, because the more oxygen in the cylinder, the more power."

The E-TEC G2 engines are Evinrude's second generation two-cycle engines using fuel injection, but the first to be designed in silico. "Previous generations of direct injection engines were primarily adaptations of the fuel system from

an existing carbureted engine," Westhoff says. "With direct injection, you have the ability to manage the fuel flow that you don't have with a carburetor. This is new technology."

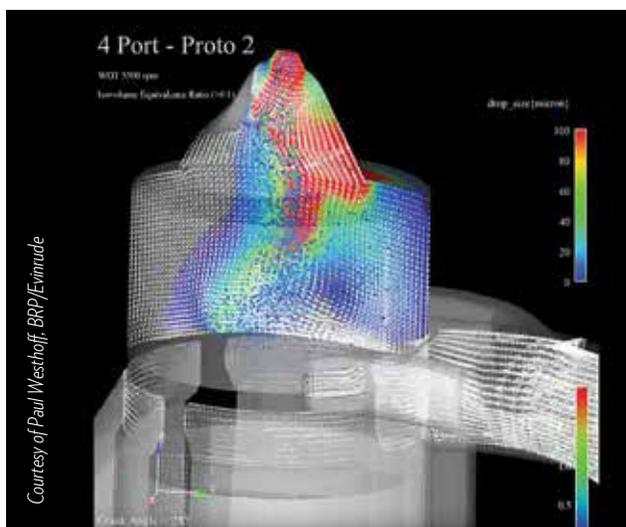
Do-overs are almost free with computer design, he adds. "Using computer modeling, we can do hundreds of runs and explore potentially high-benefit, high-risk paths. If we had to prototype them, we would run out of money."

But that's only true if the model is "smart enough" to emulate the real world of air, fuel and moving metal. And here, Reitz says, KIVA has benefited from the hallway full of test engines at the Engine Research Center that are used to confirm and improve the fluid-dynamics software.

The KIVA software doesn't only evaluate

designs; it also explains why they behave as they do, Westhoff adds. "An engine can be a black box, but this helps us understand the physics. If you look at the three-dimensional modeling results, they can make you think differently, and that leads to other ideas. The result is not your grandpa's two-stroke."

"Using computer modeling, we can do hundreds of runs and explore potentially high-benefit, high-risk paths. If we had to prototype them, we would run out of money."—Paul Westhoff



Air motion and fuel spray inside the cylinder of a fuel-injected two-cycle outboard engine is represented in the KIVA engine simulation software. The air loops around the cylinder (white arrows) and fuel is sprayed in at the top. As the piston approaches the top, the air-fuel mix is ignited, pushing the piston down to finish the cycle.

BIOLOGICAL SUPPLIER PROSPERS

WITH AID OF UW MANUFACTURING EXPERTISE

A Madison lab that produces custom-made proteins and antibodies has taken advantage of UW–Madison expertise in quick response manufacturing to bring products to market more quickly and improve profits.

In May, the collaboration between Aldevron and the Center for Quick Response Manufacturing (QRM) was awarded the top prize in the 2016 Applied Research Challenge for the development of methods to make faster, better decisions in biomanufacturing. The award was made by the Production and Operations Management Society.

From the microorganisms it grows, Aldevron extracts a wide variety of biological substances, including DNA, enzymes, anti-bodies and other proteins—all made to order.

The company employs 18 in Madison, and is headquartered in Fargo, North Dakota.

Aldevron's market includes pharmaceutical and biotech firms involved in drug discovery and other aspects of personalized medicine. "Our clients need a variety of biological products made to their specifications," says Tom Foti, vice president and

general manager of Aldevron's Madison lab. "We have finished more than 700 projects and made thousands of proteins."

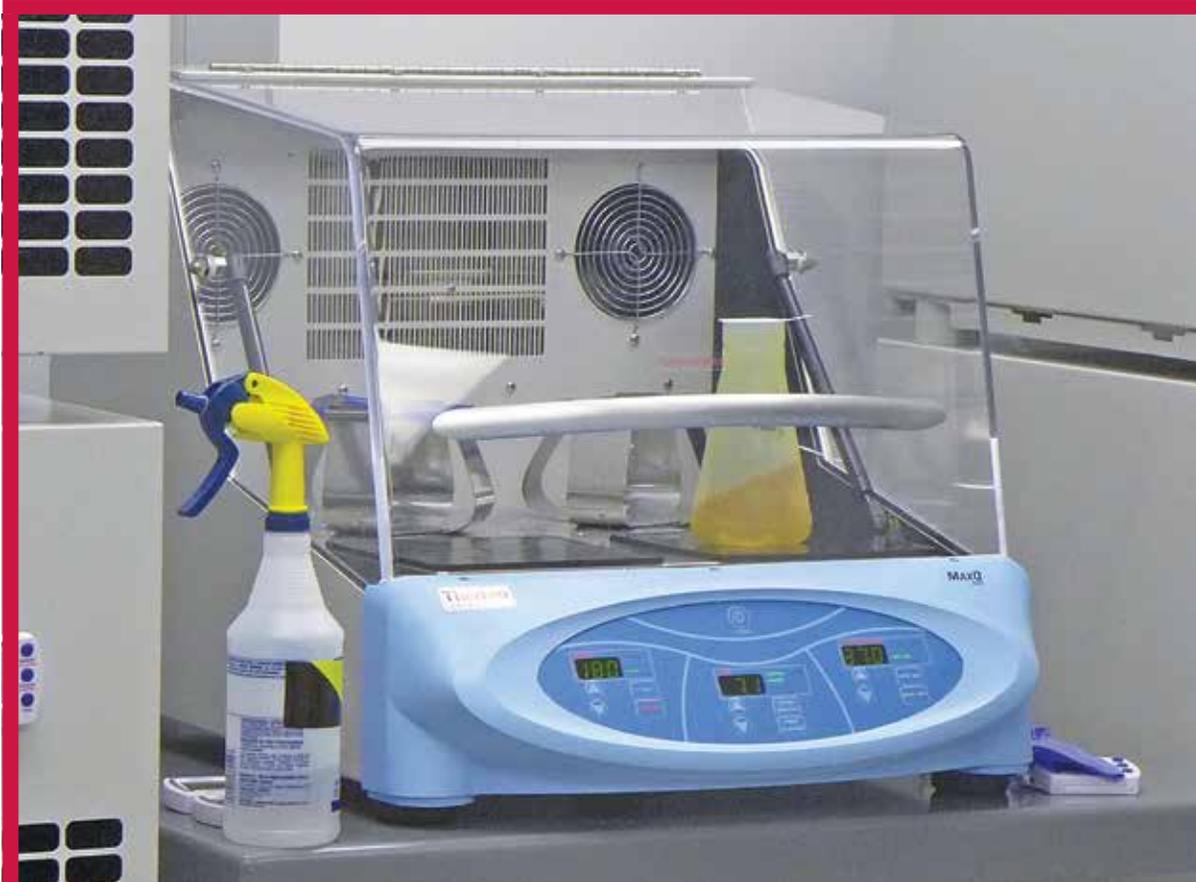
The world of drug discovery is being fueled by drugs called monoclonal antibodies—large, complicated molecules made by bioengineered cells, Foti says. For example, Humira, used to treat inflammatory diseases like rheumatoid arthritis, had sales of \$3.5 billion in the first quarter of 2016.

Speed matters in drug development, since it can lead to valuable patents that protect inventors' rights to their inventions. But producing molecules inside cells can be tricky, Foti says. "You have inherent variability, and you have to manage variables that are absent in most other industries: How fast do the cells grow? When is the optimal time to harvest the cells? Different cells or strains may process DNA, RNA or proteins differently, depending on growth conditions such as temperature, cell density, oxygen level and pH."

Typically, Aldevron makes products in three steps: A scouting run explores the variables, checks behavior of the product, and settles on the best method. A verification run tests that the



Melissa Suzuki at Aldevron explains a membrane-based flow filtration system that quickly reduces the volume of a solution using low-pressure osmosis. Aldevron works with UW–Madison's QRM center to bring products to market more quickly and increase profits. *Photo: David Tenenbaum*



Bacteria growing in flasks on this shaking incubator provide the raw material for Aldevron's products. After the cells are removed from the incubator, the product is extracted, purified and tested before shipment. *Photo: David Tenenbaum*

chosen method is optimal for quality and productivity. A production run yields the quantity required by the customer.

In 2013, Aldevron sought to increase its competitive advantages by working with the QRM center on campus. Director Ananth Krishnamurthy, an associate professor of industrial and systems engineering, explains that QRM is a set of manufacturing principles focused on exploiting "the power of time" by examining organization structure, system dynamics and application throughout an enterprise.

Reducing lead time through QRM allows a manufacturer to gain a quantum improvement in competitiveness and quality, with reduced cost and improved efficiency, says Krishnamurthy.

"QRM helped us think about how we can eliminate or mitigate the variability and risks associated with producing products inside of living cells," says Foti.

Since its establishment in 1993, the QRM center has more typically focused on traditional manufacturing, yet biological production is a natural fit, says Krishnamurthy. "We needed a good understanding of what they do so we could develop methods and tools that allow them to reduce lead time."

At Aldevron, even before production starts, QRM's statistical methods can squelch over-promising and under-delivering, Krishnamurthy says. "If you can't do something, given the timeline, required quality and cost, you would rather know sooner than later. Our math can support decision-making to determine the best case scenario, and if that is not good enough, you can cut your losses while maintaining a good relationship with the client."



The same tools help further on, Krishnamurthy says. "Failure in the production run is very expensive. It's less expensive to fail in the scouting run." Data from the scouting run may also eliminate the need for the mid-scale qualification step.

The application of QRM to biology represents the wave of the future, Krishnamurthy says. "Reducing the lead time for a high mix, custom-engineered environment is not just relevant to biologicals. That's the way manufacturing in general is headed."

View a video of the collaboration: youtu.be/CW0Q5oFTZfY

2016 Distinguished Achievement Awards

Our Distinguished Achievement Award recipients already have enjoyed long, successful careers—yet fully embrace the idea that there's more work to be done, there's another challenge around the corner.

KIM CHRISTOPHER

BSIE '81

(MBA '88, University of Minnesota)

**Director of Product Management,
Optum Solutions and Technology**

Christopher has worked in fields as diverse as avionics, transportation, medical devices and healthcare—in roles that range



from manufacturing engineering and product development to sales, marketing and corporate communications. "I've never had one minute of boredom in my 35-year career," she says. She and her husband, Dave, lived and worked in Minneapolis for 30 years, but recently, they built their dream home on a bluff overlooking a section of the Mississippi River known as Lake Pepin. So now both she and Dave telecommute from what Christopher calls the "best office ever": a home office in which they're eye to eye with the bald eagles that nest along the river. We recognized Christopher for her contributions and leadership in quality improvement and strategic product development across industries.

GARY KRELLENSTEIN

BSNE '79

(MBA '81, Cornell University, post master's degree, computer applications '84, New York University)

Consultant

A self-described "movie geek," Krellenstein grew up in New York and almost applied to college as a film major. But the



energy crisis of the 1970s convinced him otherwise, and to his surprise, he majored in engineering and found he liked it. Although semi-retired now, he spent much of his career as an investment banker, mainly in the J.P. Morgan energy group on Wall Street. He credits his wife, Catharine, for encouraging him to leave the comfort of an engineering career and take a position in the financial industry.

Krellenstein says that back in the early 1980s, when he started working at J.P. Morgan, very few people had a technical background and his nuclear engineering education differentiated him from his co-workers and gave him an edge when it came to energy finance. We honored Krellenstein as an expert in energy finance and analysis who has leveraged his technical background to promote alternative energy technologies such as nuclear, wind and solar.

JUN LEE

BSCE '68, MSCE '69, PhDCE '73

President, SRI Design

A native of Hong Kong, Lee almost ended up at the University of Michigan. But at the time, Michigan had a policy of not admitting foreign freshmen, so ultimately, he chose UW-Madison instead. And he has been in the Madison area ever since. Lee earned his bachelor's, master's and PhD degrees in civil engineering. A few years after that, he founded the structural engineering consulting firm SRI Design—and Lee is proud of the fact that his company is versatile enough to design many types of buildings ranging from university facilities across Wisconsin to a racing stadium in Tehran, Iran. When he's not at work, he enjoys watching or playing sports—and he is a talented vocalist who loves to sing music in just about any genre you can imagine. We honored Lee for his contributions as a structural engineer, entrepreneur and philanthropist.



BOYD MUELLER

MSMetE '83, PhDMetE '86

(BSMetE '82, Michigan Technological University)

**Vice President of Technology,
Alcoa Power and Propulsion**

Mueller earned his bachelor's degree from Michigan Technological University, but came here for both his



master's and PhD degrees because of the reputation of his advisor, MS&E Professor John Perepezko. At Alcoa Power and Propulsion, he works on aerospace components for jet engines. "I enjoy getting up in the morning and coming to work," he says. And while his education was critical in advancing his career, as someone who leads other engineers, he values the thought process he learned as a graduate student. "A critical, discerning thought process is a trait engineers possess, and if you combine a disciplined thought process with creativity, you have a really good researcher," he says. We honored Mueller for his pioneering work in incorporating integrated computational materials engineering into industrial production.

FRANK SANDERS

MSMSE '92

(BSME '89, University of Illinois; MBA '07 Northwestern Univ.)

**Vice President, Technology/Manufacturing
Group; Director, Global Systems
Supply Chain and Technology Enabling,
Intel Corp.**

Sanders' undergraduate training is in mechanical engineering, but he made the shift into manufacturing because it provided him greater opportunities to inter-



act with people and he chose UW-Madison for his master's degree because it was among the few universities that offered a graduate program in manufacturing systems engineering. As a student here, he also appreciated the ability to have a broader impact through work with our Engineering Summer Program, as a teaching assistant, as an ambassador during prospective student visits, and as a mentor to many undergrad minority students. And he says one of the things that really stood out about UW-Madison is the strong positions people took on issues that affected society—and that's something that greatly influenced how he approaches his work at Intel to this day. We honored Sanders as a highly successful leader and executive who selflessly works as a champion of diversity and a mentor and inspiration to many young people.

STEPHEN H. SIEGELE

BSCHE '84

Chief Executive and Consultant

Even though Siegele started out at UW-Madison as a business major, he says his chemical engineering degree and experiences in the College of Engineering were critical to his career. As a result, with the strong support of his wife, Julie, he started his first successful business—Advanced Delivery & Chemical Systems—four years after he graduated from UW-Madison. Siegele calls himself a “serial entrepreneur, always looking for or developing new technologies to commercialize.” He has spent nearly three decades as an inventor, executive, investor, and consultant. We honored Siegele for his entrepreneurial impact and leadership role in advancing the chemical industry worldwide.



XINGYI XU

MSECE '83, PhDECE '90

(BSEE '82, Huazhong University of Science & Technology
Wehan, China)

Founding president,
Shanghai Dajun Technologies, Inc.

A common thread throughout Xu's education is our Wisconsin Electric Machines and Power Electronics Consortium. He directly credits the applied power engineering education he received here to the success he's achieved as an entrepreneur. He also values the close relationships he developed with the power engineering faculty members, including Ted Bernstein, Don Novotny, Bob Lorenz, Tom Lipo, and Deepak Divan, as well as people in the Madison community who helped him and other foreign students feel welcome and included. After graduating, Xu ultimately worked for Ford for 10 years before making the decision to return to China, where he founded Dajun Technologies to pursue electric vehicle technology. We recognized Xu as an entrepreneur and leader in electric drive technology that significantly addresses the future of global transportation and industrial needs.



2016 Early Career Achievement Awards

*Our early-career award honors young alumni
whose exceptional accomplishments command the respect of their peers.*

NICHOLAS BALSTER

BSMS&E '00

(MBA '13, Babson College)

Vice President of Industrial Applications,
Groom Energy Solutions

At Groom Energy Solutions, Balster works with industrial market companies on energy technology projects that help reduce their energy consumption, save money, and positively affect the environment. He says that one aspect of his education that still serves him well today is the idea that to be a successful engineer, you have to be able to constantly change and continuously innovate—and as an illustration of that, just a couple of years ago, he also earned a master of business administration degree. We recognized Balster for his technical and leadership capabilities in advancing not only the manufacturing of cast components, but also industrial energy efficiency.



JONATHAN BARAN

BSBME '08, MSBME '10

Co-founder and CEO
healthfinch

After earning his bachelor's degree in biomedical engineering, Baran went to work for a big company and decided the corporate world wasn't for him. So he came back for a master's degree in biomedical engineering. It was then, he says: “I had the opportunity to work with incredibly intelligent, diverse people and to find my passion, which turned out to be entrepreneurship. I learned that when you follow your passion, you never have to work a day in your life.” So in 2011, he co-founded healthfinch to automate aspects of the healthcare process. Today, the company employs more than 30 people and has raised more than \$10 million in venture capital. We recognized him for the innovative ways in which he is improving efficiency in the healthcare system.



JAMES HILLIER

BSCHE '00

(BS Biochem '00, BS Molecular Biology '00)

Chief of Staff for Global Manufacturing
and Refining, LyondellBassell

You could say Hillier made the most of his time on campus. As a student here, he majored not only in chemical engineering, but also in biochemistry and molecular biology. He also played tuba in the UW Marching Band for five years—and that's also how he met his wife. In his career, he says he is most proud of advancing co-op and new-hire engineer development with the company. We honored him for an outstanding record of technical and business leadership within his company and his industry.



JENNA MARQUARD

MSIE '04, PhDIIE '07

(BSIE '03, University of Iowa)

Associate Professor,
Mechanical & Industrial Engineering
University of Massachusetts-Amherst

At the University of Massachusetts at Amherst, Marquard researches ways to help provide information to doctors, nurses and patients so they can make better decisions about improving health and healthcare. She cites several ISyE faculty members here—Patti Brennan, Steve Robinson, David Zimmerman, and Pascale Carayon—who became mentors for her. She, in turn, maintains a strong connection with her students, and says one of her proudest moments as a faculty member was when she graduated her first PhD student. We recognized Marquard as a role model whose research has helped accelerate the integration of important patient data into medical records.



ECE ALUMNUS VINCENT CHAN CONTRIBUTES TO GREAT PEOPLE SCHOLARSHIP FUND

UW-Madison prepares students to become lifelong leaders for one of the lowest tuition rates among the nation's top-10 public universities, yet the cost still presents a barrier to some scholars from low-income families.

To enable access to top-quality education, the UW-Madison Great People scholarship program provided need-based financial aid to 66 engineering students through the office of financial aid in 2015. In the future, the college will be able to support even more engineering scholars, thanks to a generous gift to the fund from electrical and computer engineering alumnus Vincent Chan (BS '72, MS '73, PhD '75).

"The scholarship is my way of thanking UW for the great education I received," says Chan, who currently resides in Del Mar, California, with his spouse, Pauline.

Chan applies his expertise in fusion physics as director of theory and computational science at General Atomics in San Diego. He also serves on numerous governmental panels and advisory boards, including the American Physical Society, and the University of Wisconsin College of Engineering Industrial Advisory Board. He is a fellow of the American Physical



**"The scholarship is my way of thanking
UW-Madison for the great education
I received."—Vincent Chan**

Society, and in early 2010 the Chinese National Office for Science and Technology Awards honored Chan at the Great Hall of the People in Beijing with the 2009 International Science and Technology Cooperation Award of the People's Republic of China for his contributions toward promoting Sino-USA magnetic fusion research collaboration.

Throughout his career, Chan promoted strong linkage between theory and experiment, and advanced understanding of fusion energy by applying high-throughput computing to elucidate theoretical challenges in magnetized plasmas. His research moved the fields of burning plasma and economical fusion forward with over 100 high-impact publications.

Chan hopes his contribution will enable future generations to similarly pursue their ambitions. His gift adds to the fund's \$44 million pool of support for all UW-Madison students, enabled by an ongoing \$20 million UW Foundation matching initiative, announced in 2008.



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College of Engineering
STORE**
store.engr.wisc.edu

As Jim Meister (BSNE '78) looks back over his distinguished career in the nuclear industry, he says there's no doubt that his UW-Madison engineering education put him on a path for success. To show his appreciation, he has been active supporter of the Department of Engineering Physics for years. A recent matching gift opportunity inspired Meister and his wife, Connie, who is also a UW-Madison graduate, to increase their support.

The Meisters, of St. Charles, Illinois, recently made a gift to the Department of Engineering Physics to establish the Jim and Connie Meister Graduate Fellowship for the nuclear engineering program. The gift was matched by UW-Madison alumni Ab and Nancy Nicholas, who announced a \$50 million matching gift opportunity in June 2015.

≡ SUPPORTING THE ≡ NEXT GENERATION OF NUCLEAR ENGINEERS

"The Nicholas match certainly influenced us," Meister says. "The opportunity to double the money for your gift is unique, and to the level that we could participate we wanted to make sure that some of the Nicholas money went into engineering."

Meister recently retired as vice president of operations support at Exelon Nuclear, operator of the largest nuclear reactor fleet in the United States, including 23 operating reactors at 14 stations spread across six states. He has been involved with many facets of Exelon's operation, including engineering, maintenance, security and emergency preparedness, and he served as co-chair of the Electric Power Research Institute Low Level Waste and Radiation Management Area Planning Committee.

Most recently, Meister has been a member of the Nuclear Energy Institute Security Working Group, whose role is to establish security and cyber security policies for the nuclear industry, and has been the executive sponsor of significant safety improvements to the Exelon fleet following the Fukushima-Daiichi accident in Japan. From 2002 through 2008, he was a member of the industrial advisory board for the Department of Engineering Physics, and since 2007 he has served as a member of the College of Engineering Industrial Advisory Board.

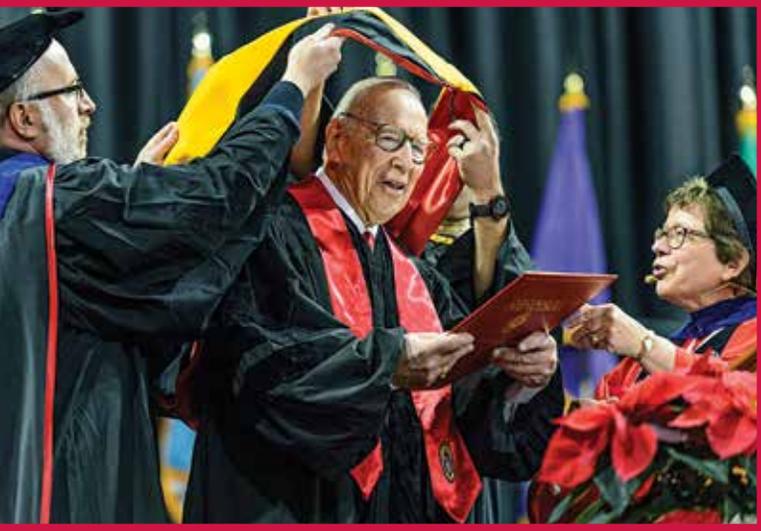
Meister says he established the graduate fellowship as a way to help move nuclear energy forward and launch the careers of the next generation of UW-Madison's nuclear engineers. "Financial support allows the department to continue with research activities that will find solutions to the challenges that my business, nuclear power, faces," Meister says. "If Connie and I can contribute to that by supporting graduate students, who are tremendously gifted thinkers, I think it will help make a difference in the long run for a business that I've been in for the last 38 years."

Meister and his family have strong ties to UW-Madison. He met Connie Robertson in their first class at UW-Madison and the two married in 1978. Two of their children, Carrie and John, are UW-Madison graduates and are married to UW-Madison graduates. Their third child, Craig, graduated from UW-Madison in spring 2016. "We've been extremely lucky in the opportunities we've had, and I don't think those opportunities would've been possible without the skills we learned and developed through our time at UW-Madison," Connie says.

As the Meisters were inspired by the Nicholas match, they hope their gift will help encourage others to give to UW-Madison. "The quality of the engineering education and research at UW-Madison is in line with the best universities in the country, and for it to stay that way is not only a challenge for the state of Wisconsin—as alumni, we also need to recognize the many excellent opportunities we had based on the quality of the university, and we should do what we can to ensure UW-Madison remains a world-class university and that those opportunities are there into the future," Meister says.



"We've been extremely lucky in the opportunities we've had, and I don't think those opportunities would've been possible without the skills we learned and developed through our time at UW-Madison."—Connie Meister



ASTRONAUT, AVIATOR, MECHANICAL ENGINEER

JIM LOVELL

RECEIVES HONORARY PHD FROM UW-MADISON

He is a cool, competent leader—a quiet hero—who played a role in turning an almost-certain tragedy into one of the greatest success stories our country has known. Marking its 45th anniversary in 2015, the *Apollo 13* mission to the moon was a failure—yet, said Captain James A. Lovell Jr. in a September 2010 interview: “I realized it really was a triumph in the way people handled a crisis: Good leadership at all levels at NASA, the use of imagination and initiative to figure out how to get us home by using just what we had on board, the perseverance of people who kept on going when it looked like initially that we didn’t have a chance. ... This is why *Apollo 13* went from being a failure to a triumph.”

Lovell certainly is an astronaut-hero, a pioneer in efforts to explore beyond the everyday world, and to generate new knowledge in an era when the average person gazed up at the sky and saw mystery in the sun, moon and stars. Lovell also was a pilot in the U.S. Navy and a successful businessman. But even greater than those, he continues to be an inspiration to many generations of people young and old, piquing their interest in science and technology, encouraging them to be bold in their aspirations and to turn the impossible into reality. And at the winter 2016 commencement ceremony, retired Captain James A. Lovell received an honorary doctorate degree from the UW-Madison. Lovell also was the commencement speaker.

Lovell was born in Cleveland, Ohio, in 1928 and moved to Milwaukee, where he graduated from Juneau High School. He also was an Eagle Scout. He attended UW-Madison for mechanical engineering and naval sciences for two years before moving on to the United States Naval Academy, graduating in 1952. He then was commissioned an ensign in the Navy. He served many flight assignments, attended pilot training, served at sea flying F2H Banshee night fighters, and was a flight instructor and safety engineer. In January 1958, he entered a



six-month test pilot training course at the Naval Air Test Center and subsequently was selected as an astronaut candidate. (Lovell ultimately retired from the Navy in 1973 as a captain.) He was the pilot of *Gemini 7* in 1965 and the commander of *Gemini 12* in 1966. *Gemini 7* was the 12th American manned spaceflight, orbiting Earth 206 times, while *Gemini 12* was the final manned *Gemini* flight.

Lovell lifted off as commander of *Apollo 13* on April 11, 1970, with Jack Swigert and Fred Haise. He and Haise were to land on the moon. But on April 13, while in transit to the moon, a routine cryogenic oxygen tank stir damaged wire insulation, creating a short and explosion inside the tank. The explosion damaged the second oxygen tank, and in just over two hours, all on-board oxygen was lost, disabling the hydrogen fuel cells that provided electrical power to the command/service module *Odyssey*. The moon landing mission was aborted, and the sole objective was to safely return the crew to Earth. Using the lunar module as a “lifeboat” providing battery power, oxygen and propulsion, Lovell and his crew re-established the free return trajectory that they had left, and swung around the moon to return home. Based on the flight controllers’ calculations made on Earth, Lovell had to adjust the course two times by manually controlling the lunar module’s thrusters and engine, using his watch for timing. *Apollo 13* returned safely to Earth on April 17. “To be sure, his legendary position as a trail-blazing astronaut has been etched in history through his command of the dramatic and fateful *Apollo 13* mission,” says Elliot Holokauahi Pulham, CEO of the Space Foundation. “Jim’s command of *Apollo 13* is often regarded as the single-most important human space exploration of all time—not because everything went perfectly, but because it did not, and in the challenges of bringing home a crew of

three using the functional remains of a seriously damaged spacecraft, Jim Lovell and the NASA team demonstrated to the world the indomitability of the human spirit, and the limitlessness of human ingenuity and the ability to triumph over all odds.”

This mission ultimately led to an Academy Award-winning movie, based on Lovell’s book of the same name, in which Tom Hanks played the role of Lovell. The beauty of the film was its portrayal of the ingenuity required of those aboard *Apollo 13* and in the control center, as they worked together to find a way to get the astronauts back to Earth. This is the essence of modern engineering, in which large, interdisciplinary teams work together to solve the critical problems we all face, including energy, water, health and many other critical aspects of our lives. This has inspired many students to pursue engineering as a career and it is a great benefit to us all.

Many are aware of Lovell’s accomplishments as an astronaut; however, he also has devoted countless hours to his country and the state of Wisconsin. Lovell has been chairman of the President’s Council on Fitness, Sports & Nutrition, served on numerous boards for corporations, universities, and nonprofits, and given inspirational speeches nationwide. “He is a man of infinite commitment to the improvement of humankind, who has given countless hours of his time sharing the lessons of life—inspiring tens of thousands of young people in the process,” says Pulham. “Whether lecturing at a university, throwing out the first pitch at a ball game, testifying before Congress, or giving career advice at space industry gatherings, Jim has been a master at the art of ‘giving back.’ He has never been one to rest on his laurels or bask in his fame. Rather, Jim Lovell has always stepped forward, encouraging others to reach for their dreams, and to boldly go where no one has gone before.”

Lovell has channeled that ‘fame’ in his efforts to be an inspiration and a role model to many. In March of 2010, he and retired Apollo astronauts Gene Cernan and Neil Armstrong visited members of the

U.S. Air Force in Southwest Asia, while on a USO tour.

Concerned with healthy aging, he appeared in a promotional video in 2014 for NorthShore University Health System. In the video, “Captain Jim Lovell’s Story: Healthy Aging,” he spoke of health challenges he has faced, and he talked about the challenges of aging and ways to stay active.

In fact, in his late 80s, Lovell still continues to speak and inspire. In summer 2015, for example, Lovell appeared in the public service announcement, “Explore and Soar,” for the Chicago Public Library System. The PSA was narrated by Bill Kurtis and appeared on all Chicago television stations through Sept. 1, 2015.

He has always strongly urged students to pursue interests in science and mathematics, and to get involved in the country’s space program. Lovell regularly visits colleges, universities and businesses where he gives talks about leadership and his experiences as a test pilot, astronaut and businessman. “From humble roots, Jim worked hard for his many accomplishments and truly believes anything is possible if you set your mind to it,” says Michelle Larson, president and CEO of the Adler Planetarium. “His infectious laughter is second only to his optimism, which shines through as he relates the challenges he has encountered and overcome throughout his career. When speaking to young people, Jim highlights the opportunities that didn’t work out the first time for him, like not making the final selection to the Mercury Seven astronaut crew. Jim is fond of saying, ‘If you want to be successful as an astronaut or anything else, you have to keep trying.’”

For his pioneering work as an astronaut, engineer and test pilot; for his many years of public service; in recognition of his years as a citizen of the state of Wisconsin; for his time as a student at UW-Madison; and for his role in inspiring millions pursue interests in math, science, engineering, aerospace and technology, UW-Madison was pleased to present James A. Lovell an Honorary Doctorate of Science.





INTRODUCING THE FACULTY WHO JOINED US IN 2016

Building nuclear reactors to withstand changing environments



ADRIEN COUET
Assistant Professor
Engineering Physics

Using computer models to improve materials for many applications



JIAMIAN HU
Assistant Professor
Materials Science and Engineering
Fellow, Grainger Institute for Engineering

Developing new tools for biological imaging



JAN HUISKEN
Visiting Professor
Biomedical Engineering

Mining big data for big attitudes



VARUN JOG
Assistant Professor
Electrical and Computer Engineering
Fellow, Grainger Institute for Engineering

Uncovering new phenomena in electronic materials



JASON KAWASAKI
Assistant Professor
Materials Science and Engineering

Keeping medical implants safe and secure



YOUNGHYUN KIM
Assistant Professor
Electrical and Computer Engineering

Applying abstract math to real-world situations



PO-LING LOH
Assistant Professor
Electrical and Computer Engineering
Fellow, Grainger Institute for Engineering

Bridging varying scales with new applications



WENXIAO PAN
Assistant Professor
Mechanical Engineering

Speeding up machine learning pipelines



DIMITRIS PAPAILIOPOULOS
Assistant Professor
Electrical and Computer Engineering
Fellow, Grainger Institute for Engineering

Developing mathematical tools for numerical simulations in engineering



BENJAMIN PEHERSTORFER
Assistant Professor
Mechanical Engineering
Fellow, Grainger Institute for Engineering

Maintaining the integrity of structural materials



PAVANA PRABHAKAR
Assistant Professor
Civil and Environmental Engineering

Studying mechanics and morphology evolution in materials



SHIVA RUDRARAJU
Assistant Professor
Mechanical Engineering
Fellow, Grainger Institute for Engineering

Following the light to better cancer treatment



MELISSA SKALA
Assistant Professor
Biomedical Engineering

Simulating the behavior of biologically active nanoparticles



REID VAN LEHN
Assistant Professor
Chemical and Biological Engineering

Using computational imaging when regular imaging is possible



ANDREAS VELTEN
Assistant Professor
Electrical and Computer Engineering

Forecasting floods with eyes in the sky



DANIEL WRIGHT
Assistant Professor
Civil and Environmental Engineering