COLLEGE OF ENGINEERING UNIVERSITY OF WISCONSIN-MADISON 2020

PERSPECTIVE

WORKING TOGETHER, WE CHANGE LIVES

How our engineers are driving electrotherapy advances

Living in harmony with water

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College of Engineering
UNIVERSITY OF WISCONSIN–MADISON

PERSPECTIVE
MAGAZINE

ENGINEERING EXTERNAL RELATIONS

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GREETINGS FROM MADISON!

When I welcome new students to our campus, one of the things I tell them is that it is a good time to be an engineer.

First and foremost, engineering is critical to advancing our economy and our society. Engineers' training and expertise enables them to play a leading role in solving challenges in healthcare, technology, information, computing, security, energy, materials, infrastructure, the environment, manufacturing, and many other areas.

In other words, they can and do make a difference.

Our college has a long history of providing the kind of engineering education that empowers graduates to think strategically, work creatively, act ethically, and lead confidently. As a result, Wisconsin engineers stand out as job candidates and as important workplace contributors. When I meet with leaders of companies—large and small, within Wisconsin and around the nation—they tell me our engineering graduates are exceptional, and they would hire as many as they could to fill their open positions.

Approximately 1,000 of our students graduate with bachelor's degrees annually. To give you an idea of how many engineering jobs are available, at UW-Madison, our engineering students have access to an average of 12,000 job opportunities annually.

As you might imagine, many of our graduates receive multiple job offers, and because companies are competing for top engineers, the average starting salary for undergraduates in 2019 was $69,200—up from $65,900 the prior year.

Just as employer demand for our Wisconsin engineering graduates is high, so is prospective student demand for an engineering education. Currently, we enroll 4,500 undergraduates, but many more students apply than we have the capacity to admit. In the future, we would like to expand our undergraduate student body to 5,500 so that students who want to study engineering can do it and so that we can better meet demand for engineers in Wisconsin and across the country.

We are embarking on our growth strategically. For example, to maintain the quality of our students' educational experiences and ensure they have access to the courses they need, we are hiring additional faculty. As you'll read in this publication, we welcomed 19 new faculty members to our college in 2019 and now our total number of faculty exceeds 200, with more to come in 2020.

We are making the most of our space; within the past few years, for example, we opened the Jun and Sandy Lee Structures Laboratory. We have renovated instructional facilities, upgraded research space, and transformed the Wendt Commons building into four stories of state-of-the-art undergraduate-focused space that includes classrooms, small- and large-group study spaces, our makerspace, and VR/data visualization studios. In addition to our investments in existing infrastructure, we also have identified buildings through an engineering campus master plan that need to be replaced soon to support additional undergraduate students, enable us to recruit and retain top-tier faculty members, and sustain our excellence in research and graduate education.

The U.S. Bureau of Labor Statistics expects that between 2016 and 2026, there will be 140,000 new jobs for engineers, and the strides we have made are critical starting points in our ability to produce more engineering graduates to keep pace with industry growth. Our expansion is a top priority for UW-Madison, and I am looking forward to telling you more about our progress as it unfolds.

ON, WISCONSIN!

Ian M. Robertson

Dean Ian Robertson

(photo from Feb 2020 career fair)

Fast facts

- 4,500 undergraduate students; 1,000 graduates annually
- 50% of our undergraduate students are from Wisconsin
- 1,500 graduate students; 420 graduates annually
- 3,700 employers recruit our engineers annually
- 70% of our engineering graduates stay and work in the Midwest
- 16,000 engineering alumni in Wisconsin; 45,000 worldwide

DIFFERENTIATION ROADMAP

The path a stem cell takes toward its identity as a fully defined cell, the analogy goes, is like a ball rolling down a hill. Along the way, it encounters bumps, obstacles and varied terrain that influence its final destination.

And while it's not currently possible for stem cell researchers to see each transition in a cell's state in real time, Biomedical Engineering Assistant Professor Melissa Kinney and collaborators have developed a versatile computational method that can provide snapshots not only of stem cell differentiation, but of cells and processes beyond.

"We are calling it a pipeline or a roadmap," she says. "Our roadmap is intended to help investigators connect the types of questions they want to ask with relevant computational tools, because everyone's questions are going to be slightly different."

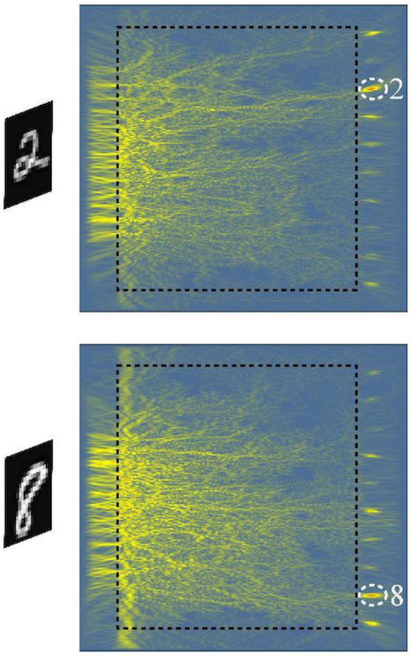
She and her collaborators already have used their method to identify a protein, ErbB4, that was not previously known to influence red blood cell development. The finding moves them incrementally closer in their quest to produce fully developed red blood cells in a dish.

More: go.wisc.edu/perspective2020-differentiation

While it's not currently possible for stem cell researchers to see each transition in a cell's state in real time, BME Professor Melissa Kinney and collaborators have developed a versatile computational method that can provide snapshots not only of stem cell differentiation, but of cells and processes beyond.

SMART GLASS

From left to right, Zongfu Yu, Ang Chen and Erfan Khoram developed the concept for a "smart" piece of glass that recognizes images without any external power or circuits. *Photo: Sam Million-Weaver.*



Artificial intelligence gobbles up substantial computational resources (and battery life) every time you glance at your phone to unlock it with face ID. In the future, one piece of glass could recognize your face without requiring any sensors or circuits or power sources.

Electrical and Computer Engineering Associate Professor Zongfu Yu and collaborators have made this simple piece of glass smart:

"We're using optics to condense the normal setup of cameras, sensors and deep neural networks into a single piece of thin glass," says Yu.

Tiny strategically placed bubbles and impurities embedded within the glass bend light in specific ways to differentiate among different images. That's the artificial intelligence in action.

For their proof of concept, the engineers devised a method to make glass pieces that could detect, in real-time, when a handwritten 3 was altered to become an 8.

Read more, and view a video demonstration here:
go.wisc.edu/perspective2020-smart-glass

Nuclear forensics

Whether it has fallen into the wrong hands or is in use lawfully, nuclear material has "fingerprints" that enable researchers to trace its source and movement. At UW-Madison, experts in nuclear security are pioneering ways to speed up this analysis. Working with Engineering Physics Professor Paul Wilson, PhD student Arrielle Opotowsky is developing machine-learning methods to trace the origin of a nuclear material, while PhD student Katie Mummah is leveraging nuclear fuel-cycle simulation tools to track nuclear material throughout its lifetime.

More: go.wisc.edu/perspective2020-nuclear-forensics

Smart screening

Industrial and Systems Engineering Professor Oguzhan Alagoz and his collaborators have used mathematical modeling to identify the potential benefits and drawbacks—for example, false positives or unnecessary anxiety—of mammography screening strategies for women with Down syndrome.

More: go.wisc.edu/perspective2020-smart-screening

MIND-BENDING METAL WORK

Professor Izabela Szlufarska and postdoctoral scholar Hongliang Zhang examine data in their lab, where they've observed a particular material's internal structure shift during bending in a way that's completely new for metals. *Photo: Sam Million-Weaver.*

For nearly 100 years, scientists thought they understood everything there was to know about how metals bend.

Materials Science and Engineering Professor Izabela Szlufarska and her collaborators have proven them wrong.

The researchers discovered that when they bent the intermetallic material samarium cobalt, narrow bands with a freeform molecular configuration formed in the material's crystal lattice, rather than the regular, grid-like structure in the rest of the metal. Those amorphous bands allowed the metal to bend.

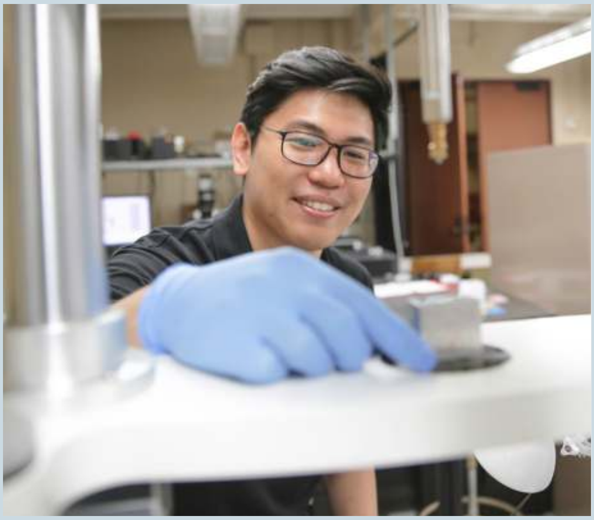
In general, techniques that increase a metal's strength make it more likely to crack under pressure because they create dislocations—tiny irregularities or mismatches in the otherwise well-ordered crystal lattice of a metal. Dislocations can move, and that's what allows a material to bend without ripping apart every single bond inside its crystal lattice at once.

On the contrary, samarium cobalt bends easily, even though its dislocations are locked in place. The surprising discovery not only upends previous notions about how metals deform, but could help guide the creation of stronger, more durable materials.

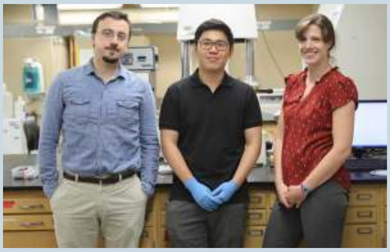
Computational and experimental expertise were key to cracking the case. "It's almost like lubrication," says Szlufarska. "We predicted this in simulations, and we also saw the amorphous shear bands in our deformation studies and transmission electron microscopy experiments."

More: **go.wisc.edu/perspective2020-metal-work**

CRACKING CARTILAGE



Above: Recent PhD graduate Guebum Han uses a state-of-the-art experimental setup to study how fractures occur in cartilage. Below: Han (center) with his co-advisors Melih Eriten and Corinne Henak. *Photos: Sarah Page.*



For athletes from pee-wee to pro, cartilage plays a crucial role in protecting joints during activities such as running and jumping. All too often, however, we read reports of high-profile players forced to make an early exit from sports such as football or basketball because their cartilage has crumbled.

Based on state-of-the-art experiments conducted by Mechanical Engineering Assistant Professor Corrine Henak, Associate Professor Melih Eriten, and their graduate student Guebum Han, we now know a fast impact significantly reduces cartilage's strength, while a load applied at a slow rate enables cartilage to withstand about 10 times the mechanical work before fracturing.

In other words, the tough but flexible tissue that covers the ends of bones at joints in the human body is quite effective at dissipating energy—but if enough force is applied, cartilage will fracture, and the body can't rebuild it.

The research could have an impact in areas as wide-ranging as athlete-specific training regimes in high-impact sports or in predicting an individual patient's risk of developing incurable osteoarthritis.

More: **go.wisc.edu/perspective2020-cartilage**

Photo: Sam Million-Weaver

HAT HAIR

Reversing baldness could be as easy as wearing a high-tech hat, thanks to a noninvasive, low-cost, hair-growth stimulating technology developed by Materials Science and Engineering Professor Xudong Wang and colleagues.

Based on devices that gather energy from a body's day-to-day motion, the hair-growth technology stimulates the skin with gentle, low-frequency electric pulses. That stimulation, which penetrates only the scalp's outermost layers, causes dormant follicles to "wake up" and reactivate hair production.

And while the technology could be used as an intervention for people in the early stages of pattern baldness, it likely wouldn't bestow cascading tresses to someone who has been as bald as a billiard ball for several years.

Developed by MS&E Professor Xudong Wang and colleagues, a new hair-growth technology uses low-frequency electric pulses to coax dormant follicles to reactivate hair production.

More: go.wisc.edu/perspective2020-hat-hair

Xudong Wang

Victor Zavala

Presidential recognition

Materials Science and Engineering Professor Xudong Wang and Chemical and Biological Engineering Associate Professor Victor Zavala were among four UW-Madison recipients of the 2019 Presidential Early Career Award for Scientists and Engineers, a recognition considered to be among the U.S. government's highest honors for early-career researchers.

The U.S. Department of Health and Human Services nominated Wang for his research developing small generators that harvest energy and produce power from movement of the human body, while the U.S. Department of Energy nominated Zavala for his computational contributions to advanced control of power systems and for his service to the educational community as an enthusiastic professor and mentor.

More: go.wisc.edu/perspective2020-presidential

MAGNETIC MEDICINE

When you take a pill, the drug passes through your system—but its healing effects can come a cost: Along the way to its intended location, the drug can dose, and harm, healthy tissues, too.

With their concept for a magnetic drug delivery system, however, Materials Science and Engineering Assistant Professor Jiamian Hu and Professor Chang-Beom Eom hope to reduce those side effects and boost a drug's efficacy by delivering it only to its intended targets within the body.

They envision nanometer-scale particles with a magnetic core and a ferroelectric shell coated with a medicine (think of peanut M&Ms), which would remain inactive until clinicians applied an external magnetic field to release it from the particles' surfaces. Doctors could use external magnets to manipulate the particles inside patients' bodies.

At the moment, it's all in theory. But, as the researchers prepare to build their vision, it's a step along the path toward truly targeted drug delivery.

More: **go.wisc.edu/perspective2020-magnetic-medicine**

With their concept for a magnetic drug delivery system, MS&E Assistant Professor Jiamian Hu and Professor Chang-Beom Eom hope to boost a drug's efficacy and reduce side effects by delivering it only to its intended targets within the body.

International honor

For their contributions to technologies that protect people's online privacy, Electrical and Computer Engineering Assistant Professor Kassem Fawaz and his collaborators earned the 2019 Caspar Bowden Award for Outstanding Research in Privacy Enhancing Technologies during the Privacy Enhancing Technologies Symposium in Stockholm, Sweden. The award recognizes their work in creating an automated tool that enables consumers to better understand today's barrage of jargon-laden online privacy policies.

More: go.wisc.edu/perspective2020-international-honor

Catalysis giant

Chemical and Biological Engineering Professor Emeritus James Dumesic earned the 2019 Eni Energy Transition Award. This internationally renowned award honors research and technological innovations that promote the transition toward low-carbon energy systems. Dumesic has made pioneering advances on novel catalytic processes for converting plant material into advanced fuels, biodegradable plastics and other renewable chemicals.

More: go.wisc.edu/perspective2020-catalysis-giant

FIGHTING FUNGI

Assistant Professor Megan McClean, right, and PhD student Stephanie Geller employed a light-controllable repressor of gene expression in a common species of yeast. *Photo: Kristen Koenig.*

Through a tool that uses light to control gene expression in yeast cells, Biomedical Engineering Assistant Professor Megan McClean and graduate student Stephanie Geller and their collaborators in Germany University are illuminating the path toward improved treatments for fungal infections.

The team generated a light-controllable repressor of gene expression in *Saccharomyces cerevisiae*, a species of yeast used in baking and brewing. Now that they've tested the tool on the yeast, the researchers are using it pathogenic yeasts as part of McClean's ongoing work to uncover new drug targets for fungal infections.

Geller, a third-year PhD student, is particularly interested in using the new approach to study the yeast Candida albicans, the culprit behind fungal infections such as oral thrush and vaginal yeast infections. The pathogenic yeast can also form biofilms on medical devices, such as catheters, and then disperse into the bloodstream, causing devastating systemic illnesses.

Fungal cells can be tricky to specifically target because their cellular components and structures are very similar to those in human cells. "Fungal infections are pretty scary, particularly as immunocompromised populations grow, and there is really a limited number of drugs to target fungi," McClean says. "They're so close to human cells. So what can you target that won't make people sick? There are four classes of drugs, and when you only have four classes of drugs, you start to see drug resistance as they're used more and more. So to get out ahead of that, what is specific to fungi that we could target to alleviate or prophylactically suppress fungal infections?

More: go.wisc.edu/perspective2020-fighting-fungi

Early-career congrats

In 2019, seven young engineering faculty members received prestigious National Science Foundation CAREER awards, which not only provide research support, but also place them among the leading early-career faculty in the nation. The award recipients include:

- Biomedical Engineering Assistant Professor **Jeremy Rogers**, who is developing a custom microscope to monitor cellular functions in the human eye and ultimately to diagnose disease.
- Civil and Environmental Engineering Assistant Professor **Paul Block**, who is developing modeling tools that predict seasonal cyanobacteria levels in lakes.
- Civil and Environmental Engineering Assistant Professor **Matt Ginder-Vogel**, who is studying the ways in which arsenic becomes mobile and ends up in our water sources.
- Electrical and Computer Engineering Assistant Professor **Younghyun Kim**, who is using a technique called approximate computing to optimize the energy use of embedded systems.
- Electrical and Computer Engineering Assistant Professor **Dimitris Papailiopoulos**, who is using coding theory to make machine learning algorithms more robust.
- Electrical and Computer Engineering Assistant Professor **Andreas Velten**, who is creating special cameras that can selectively detect fluorescence without becoming overwhelmed by massive amounts of data.
- Mechanical Engineering Assistant Professor **Sangkee Min**, who is developing new machining strategies for processing ceramic materials.

Operations: Cybersecurity

Infrastructure servers at the Wisconsin Institutes for Discovery at the University of Wisconsin-Madison. *Photo by Jeff Miller/UW-Madison.*

Laura Albert

In an age of data breaches and malware attacks, cybersecurity is paramount to organizations that store troves of customer and employee information.

However, in addition to their centralized information technology infrastructure, many large organizations rely on global supply chains comprised of third-party vendors and contractors—and any weak links can invite threats, as companies like Target or Home Depot or the United States Office of Personnel Management can attest. All have experienced major data breaches over the past six years from attacks that started with third-party vendors.

So how do organizations effectively safeguard their IT supply chains without completely exhausting their budgets? Industrial and Systems Engineering Professor Laura Albert believes the answer lies within her field of expertise: She is among the pioneers in bringing operations research to cybersecurity.

To start, she's examining supply chains to help organizations weigh the options—and tradeoffs—in these complex decisions. She and former graduate student Kaiyue "Kay" Zheng (PhDIE '17) published a series of recent papers—in the journals *Risk Analysis, Naval Research Logistics* and *IISE Transactions*—in which they propose optimization models to guard against worst-case risks and deal with adversarial attacks, where cyber assailants adapt to defensive measures. Those models provide decision-makers with a quantitative way to assess their options and identify a portfolio of security controls that may work best for their organization.

More: go.wisc.edu/perspective2020-operations-cybersecurity

"This lab will provide for that kind of visualization, which is very important for students."

— Gustavo Parra-Montesinos

Photo: Sarah Page

COLLEGE OPENS JUN AND SANDY LEE STRUCTURES LAB

Exterior view of the structures lab.
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A big new structures lab represents a leap forward for UW-Madison's structural engineering program. The College of Engineering held an official opening ceremony for the Jun and Sandy Lee Wisconsin Structures and Materials Testing Laboratory on Oct. 23, 2019.

The lab will serve the structural engineering program, which is a part of the Department of Civil and Environmental Engineering. Dean Ian Robertson said the new facility—a 2,500 square-foot addition to the structures lab in Engineering Hall—will ensure UW-Madison continues its long history as a leader in the structural engineering field.

Interior view of the structures lab.
©2019 Michael R Conway, michaelrconway.com.

"This will be a new era for our structural engineering program here at UW-Madison," says Robertson. "If you look back through the history of the College of Engineering, you will find that we've been conducting pioneering structural engineering research on our campus for more than 100 years. With this new facility and our faculty, we anticipate you'll be hearing about new advances in the field of structural engineering coming from the Department of Civil and Environmental Engineering."

The new structures lab cost roughly $3.2 million. It came to fruition through gifts from CEE friends and alumni, including a $1 million lead donation from Jun (BSCE '68, MSCE '69, PhDCE '73) and Sandy Lee (BA '69).

Jun Lee, president of the SRI Design Inc. engineering firm, often tells students, coworkers and engineers who work under him that it's vital for structural engineers to visualize what they're doing—beyond simply knowing formulas or theoretical knowledge of how a structure should perform under certain conditions.

"This lab will provide for that kind of visualization, which is very important for students," he says.

Gustavo Parra-Montesinos, the C.K. Wang Professor of Structural Engineering and structures lab director, notes the new lab will greatly improve the college's ability to carry out full-scale testing. The old lab, which opened in 1984 and will remain in use as part of the new larger facility, was sometimes limited due to space constraints.

The new lab includes an L-shaped concrete post-tensioned reaction wall that is 26 feet tall with 10-foot-deep buttresses, and a 6 ½-foot-thick post-tensioned strong floor. The wall and floor are lined with gridded high-strength anchor points, which are used to connect test specimens and fixtures such as hydraulic actuators for application of a wide variety of forces and displacements.

The lab also has a 20-ton overhead crane and opens up to allow access to the outside and the old lab, and enough space to test specimens as long as 40 feet.

Parra-Montesinos says the extra space and greatly bolstered capabilities—the 20-ton crane has a loading capacity double that of the old lab's crane—will make a big difference for students.

"They will be able to really feel how structures behave," Parra-Montesinos says. "Sometimes we show them photos or videos, but it's never the same as witnessing a structural member failing, for example—having that true experience. That will position them among the best in the nation, not only in terms of structural design, but for things like forensic engineering—how to understand what happened when a failure occurs, how to interpret cracks and skills such as that."

Hannah Blum, an assistant professor of civil and environmental engineering who specializes in structural engineering, said the new lab's larger floor allows for full-size model testing, while its height will let engineers test multi-story structures.

"You can create and run models, but how do you know if the model results are correct if you don't have some initial test results to compare them against?" Blum says. "To really understand what's happening in a structure and how all the elements interact together, you need to do a large-scale test."

Lee says the lab addition puts the College of Engineering in prime position to conduct research that few other institutions can match.

"This is, if not the most capable, one of the most capable research labs in the entire United States," he says. "It gives us an opportunity to do research projects that very few universities can do, which will deepen the knowledge of structural engineering beyond what we know now."

MEET OUR NEW FACULTY

To meet future demand for highly skilled engineers and to expand the breadth and depth of our expertise, our college has plans to grow. And in 2019, we added **19** new faculty members whose research focuses on everything from human health to energy to machine learning to advanced manufacturing and more.

BIOMEDICAL ENGINEERING

Assistant Professor **Aviad Hai** develops revolutionary next-generation tools to reveal a more comprehensive account of neural activity across the brain.

Assistant Professor **Melissa Kinney** studies cell behavior and communication on large scales to learn how systems function in the human body.

Assistant Professor **Colleen Witzenburg** studies cardiovascular tissue structure and function to predict what damage might occur after sudden events such as heart attacks or over long-term conditions like congestive heart failure.

CIVIL & ENVIRONMENTAL ENGINEERING

Assistant Professor **Jesse Hampton** studies enhanced geothermal systems, oil and gas energy extraction, energy, waste and CO2 storage and underground construction and tunneling.

Assistant Professor **Zhenhua Zhu** hopes his research will enable automation in the construction industry, sometimes called “smart construction.”

CHEMICAL & BIOLOGICAL ENGINEERING

Assistant Professor **Matt Gebbie** will focus on how molecules behave at the interfaces between solids and liquid, which is important for batteries, solar cells and other energy storage and generation devices.

ELECTRICAL & COMPUTER ENGINEERING

Assistant Professor **Kangwook Lee** hopes to extend information theory and coding beyond simple machine learning problems like linear regressions, to apply the concepts to trickier problems like deep learning.

Assistant Professor **Chu Ma** is working to take acoustic sensing, the technology behind ultrasound, to new levels.

ENGINEERING PHYSICS

Professor **Curt Bronkhorst** sheds light on how metallic materials deform and fail, which has far-reaching implications for components made of metal, including in vehicles, aircraft and countless other structures.

Assistant Professor **Jennifer Choy** will focus on developing methods to control photons and their interactions with atomic systems, which will enable better understanding and control of quantum properties.

Assistant Professor **Benedikt Geiger** focuses on research into high-temperature plasma physics, with the ultimate goal of achieving fusion energy, a potentially abundant source of environmentally friendly energy.

Assistant Professor **Yongfeng Zhang** studies how materials degrade in extreme conditions using microstructure-based modeling.

INDUSTRIAL & SYSTEMS ENGINEERING

Assistant Professor **Justin Boutilier** uses optimization and machine learning to improve healthcare access, delivery and quality, particularly in low- and middle-income settings.

MATERIALS SCIENCE & ENGINEERING

Assistant Professor **Dawei Feng** researches the combination of metals and organic molecules to create new solid state compounds with properties that could be useful in applications ranging from advanced electronics to medicine.

MECHANICAL ENGINEERING

Assistant Professor **Joseph Andrews** studies printable and flexible electronics for sensor development.

Assistant Professor **Lianyi Chen** studies metal additive manufacturing and opportunities for new material development using 3D printing.

Assistant Professor **Josh Roth** (who also holds an appointment in orthopedics and rehabilitation) investigates treatments of musculoskeletal injuries and disease, with the goal of enhancing personalized treatments for patients.

Assistant Professor **Dakotah Thompson** focuses on understanding thermal transport and energy conversion at nanometer length scales.

Assistant Professor **Xiangru Xu** designs control algorithms for autonomous and cyber-physical systems that provide safety guarantees while maintaining those systems' performance.

HITTING THE RIGHT NERVE

by Tom Ziemer

Neuromodulation therapies are surging in the medical industry, and UW-Madison biomedical engineers are pushing the field forward.

Hundreds of nerves, comprised of billions of neurons, thread throughout the human body. They're our internal wiring, forming a vast network that controls both conscious and unconscious processes, from thinking and movement to breathing and heartbeat.

And that expansive reach has neural engineers and clinicians thinking big about new ways to treat a shockingly wide array of diseases and conditions—through a technique that's both well established and still emerging.

Neuromodulation—also known as bioelectronic medicine or electroceuticals, among other monikers—entails using electricity to stimulate nerves and produce therapeutic effects.

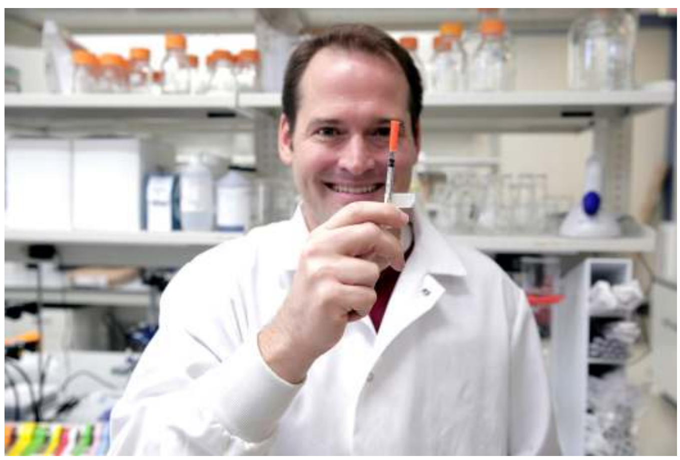
Beyond classic applications like the cardiac pacemaker and the cochlear implant, neuromodulation devices can relieve back pain, treat movement disorders such as Parkinson's disease and dystonia, prevent or curb epileptic seizures, ease depression and more. U.S. Food and Drug Administration (FDA) approvals continue to roll in for a whole slew of conditions, including heart failure, stroke, sleep apnea and obesity, and there's a steady flow of clinical trials for devices aimed at various forms of cancer, autism, schizophrenia, opioid use disorder ... and on and on.

There are even efforts to employ neuromodulation to accelerate learning, including a $10 million project led by the University of Wisconsin-Madison and funded by the U.S. Defense Advanced Research Project Agency (DARPA). In another ambitious DARPA-funded venture, University of Utah biomedical engineers enhanced a prosthetic arm to transmit sensory signals to the brain, allowing an amputee to actually feel an object (and earning a congratulatory tweet from actor Mark Hamill—Luke Skywalker himself, the LUKE Arm's namesake—in the process).

And at the same time the list of applications for neuromodulation is growing, industry and academic researchers are exploring less invasive treatments to stimulate the central nervous system via the easier-to-access peripheral nervous system. The vagus nerve, a lengthy nerve that runs from the brain to the abdomen, is the in vogue entry point for many new devices and offers an appealing alternative to more established yet invasive techniques like deep brain stimulation, which relies on electrodes implanted in the brain.

Other emerging approaches use completely noninvasive surface stimulation, like Cala Health's watch-like device for treating essential tremor, or transcranial magnetic stimulation, which employs magnetic fields to treat major depression from outside the head.

Sarah Brodnick is the program manager for a $10 million grant from the Defense Advanced Research Projects Agency at UW-Madison. *Photo: Sarah Page.*



Biomedical engineer Kip Ludwig is among UW-Madison researchers pioneering new neuromodulation technologies. *Photo: Renee Meiller.*

"This has the potential to be the most dominant medical treatment of any treatment out there in the next 10 to 15 years."

— Kip Ludwig

UW-Madison biomedical engineers, in partnership with academic collaborators and the medical device startup Neuronoff, recently made their own breakthrough in the quest for a minimally invasive stimulation scheme: an injectable, liquid electrode that solidifies inside the body and could be activated through surface stimulation.

The project is one piece of a burgeoning portfolio of neuromodulation work in the College of Engineering—in partnership with the UW-Madison School of Medicine and Public Health—covering the full research and development spectrum. Those efforts are bearing fruit in the industry, too: The medical technology company NeuroOne is pursuing FDA approval for a thin-film electrode array used to diagnose epileptic seizures, based on technology created by Vilas Distinguished Achievement Professor of Biomedical Engineering and Peter Tong Chair Justin Williams.

By all measures, the neuromodulation field is poised for serious growth. Various market research reports project the industry in the tens of billions globally within the next five years. Recent years have seen newer ventures like LivaNova, the result of a $2.7 billion international merger, and Galvani Bioelectronics, a collaboration between Google's Verily and pharmaceutical leader GlaxoSmithKline, arrive to compete with medical device giants like Medtronic, Boston Scientific and Abbott Laboratories.

"This has the potential to be the most dominant medical treatment of any treatment out there in the next 10 to 15 years," says Kip Ludwig, an associate professor of biomedical engineering at UW-Madison and a leader on the injectable electrode project. "It has had more FDA approvals—by far—in the last five years than any drugs."

Ludwig should know. He's a former program director for neural engineering at the National Institutes of Health and previously designed a minimally invasive device that recently received FDA pre-market approval for treating hypertension and heart failure.

Devices over drugs

In theory, neuromodulation, which also technically includes drug delivery devices like intrathecal pumps that target nerves, offers tantalizing specificity and control compared to traditional drugs.

Whereas a drug taken orally has to travel through the blood system to reach its destination—limiting its effectiveness, exposing a patient to potential side effects, taxing the body's receptors and, in the case of some medications, creating chemical dependency—neuromodulation treatments take a direct route.

"With neuromodulation, therapy can be given on demand and delivered precisely to a specific target," says Aaron Suminski, a senior scientist and part of the core team of researchers in neural engineering at UW-Madison. "In contrast, medicine taken orally might not be effective for some time and will eventually wear off, requiring it to be taken again and again."

Because they can both record neural activity and stimulate nerves, particularly advanced neuromodulation devices such as the NeuroPace RNS System for epilepsy and the Medtronic Micra pacemaker can measure assigned biomarkers and then stimulate as needed.

Such "closed-loop" devices are very much the exception at the moment, though; most require periodic programming sessions with a doctor for updates. That's problematic for conditions like depression where the effects of stimulation are much more gradual.

And while neuromodulation might not cause side effects in the systemic manner of traditional drugs, selectivity in stimulation remains a work in progress. As a result, many devices aren't yet consistently reliable across all patients, and their electrical current can easily bleed into off-target areas, creating unwanted effects.

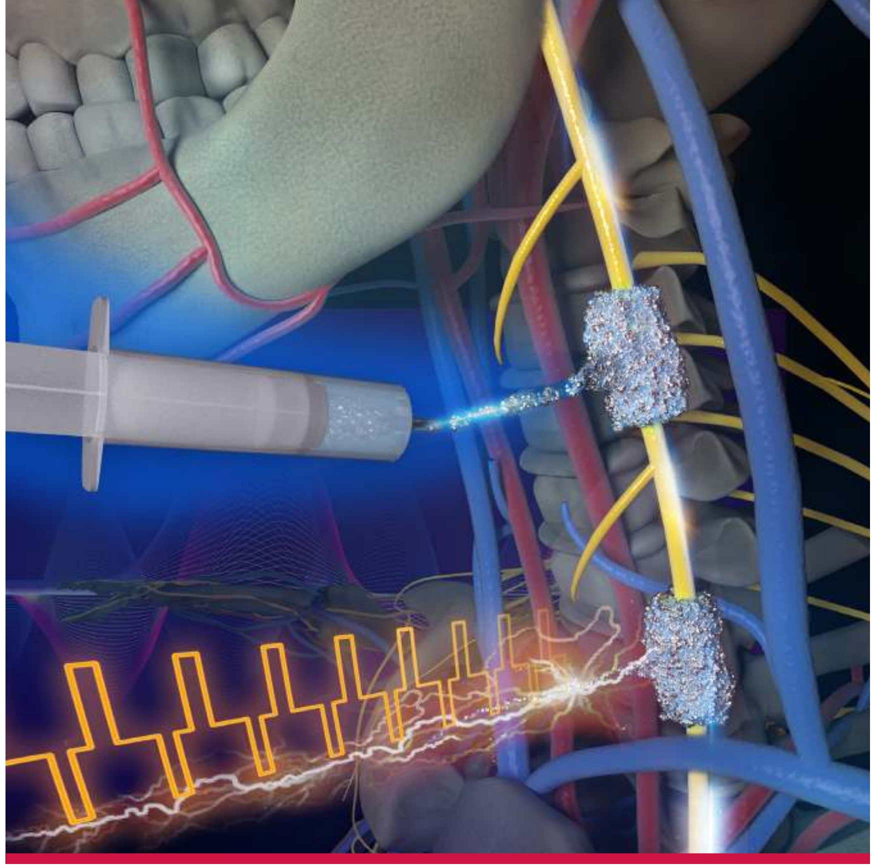
"Right now neuromodulation is pretty 'dirty' medicine," says Sarah Brodnick, a researcher and program manager for the $10 million DARPA grant at UW-Madison. "We need devices that can create a much more focal current to the intended target."

Core questions

To hone that kind of reliable precision, researchers need to revisit a seemingly basic question at the heart of the field: On a fundamental level, how exactly does neuromodulation work? While the biological mechanisms behind a few applications are understood and hypotheses exist about others, the question remains largely open.

There's also the issue of histology, or microanatomy: A human vagus nerve contains multiple fascicles—bundles of nerve fibers—that connect to different parts of the body.

"When you wrap a stimulating cuff around a human nerve, you don't really know what you're activating,"



An illustration of a minimally invasive stimulation scheme using a liquid electrode developed by UW-Madison biomedical engineers and collaborators. *Illustration by Xin Zou/Grainger Institute for Engineering.*

says Megan Settell, a PhD candidate at the Mayo Clinic Graduate School of Biomedical Sciences who's working with Ludwig at UW-Madison to better understand the anatomical organization of the vagus nerve to help optimize treatments.

Settell and Ludwig are working with collaborators at Duke University to map the reach of each fascicle in the vagus nerve and to use predictive modeling to try to understand how electrode placement contributes to side effects from stimulation.

"The analogy right now is we know we're hitting a piano keyboard with our forearm," says Ludwig. "We don't know exactly what keys we're hitting. It's kind of a muddled sound. But we want to get to the point where we can play Beethoven."

Ludwig has a plan for how to get closer to that point. It involves partnering with industry players such as LivaNova and Galvani Bioelectronics to study the effects of their already approved devices at a basic level while also honing testing models so they're more predictive of human efficacy. In essence, he wants to shorten and smooth out the road for translating devices from the lab to the clinic.

A window into what's at work

Ludwig, Williams, and a growing cadre of other UW-Madison researchers focused on translational neural engineering are also pursuing advances in optical imaging technologies that could allow them to see electrical activity—and neural activation—in real time.

They're building upon an advance by Williams and Zhenqiang "Jack" Ma, the Lynn H. Matthias Professor in Engineering and Vilas Distinguished Achievement Professor in Electrical and Computer Engineering, who developed the world's first transparent electrodes. Williams, Ludwig and Walter H. Helmerich Professor of Biomedical Engineering Kevin Eliceiri are using those electrodes in tandem with a method in which genetically encoded calcium indicators fluoresce to show when neurons fire, allowing them to glimpse a wider view of the neural activity created by neuromodulation.

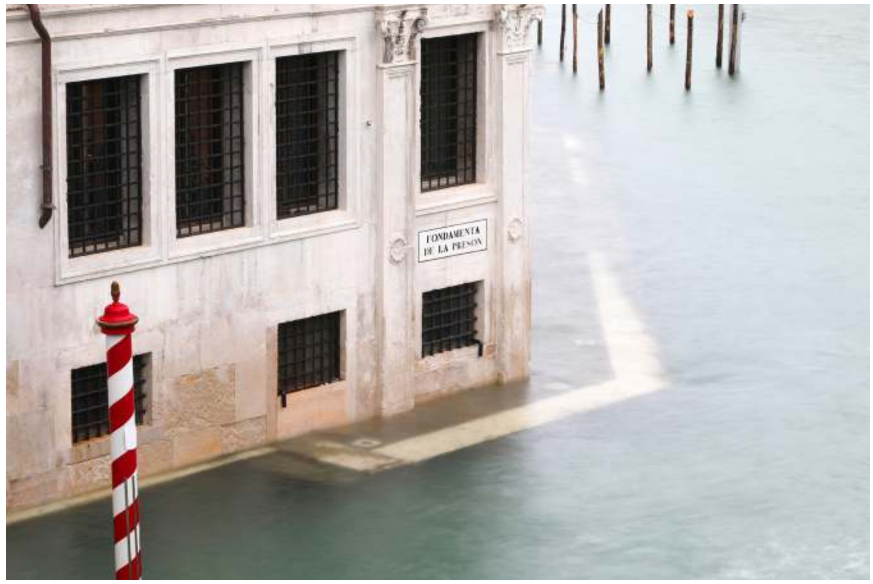
It's the kind of groundwork that could help the field realize its potential.

"Things are going to get crazy in the next 10 to 15 years," says Ludwig. "It's going to be amazing, and it will revolutionize science."

As 100-year storms increase in frequency and severity, how can humans exist in harmony with water?

LIVING ON THE EDGE

by Alex Holloway



Ancient Palace in Grand Canal in Venice, Italy, during the November 2019 flood.

Situated on more than 100 small islands, Venice, Italy, attracts upwards of 20 million tourists annually—many of whom embark on gondola rides on more than 175 canals that thread through the historic city.

But in this city renowned for its waterways, water has become a problem. A century ago, it had seven tides each year. Now, because of rising sea levels, that number is closer to 100, and in November 2019, one of those tides caused historic flooding that a local Italian governor described to a National Public Radio reporter as "apocalyptic devastation."

Just a few months earlier, a United Nations report (which cited more than 7,000 research publications) projected that by 2050, more than a billion people will live in low-lying areas vulnerable to devastating storms.

As our world changes, engineers also must grapple with renewed threats from water—for example, encroaching on coastal communities or from storms unleashing devastating floods.

Perhaps the greatest hurdle for coastal engineers is one they can't control: People like living near water, and that doesn't appear to be changing anytime soon. Think of Dubai in the United Arab Emirates, which boasts the world's largest man-made harbor and an artificial archipelago, or the Florida island city of Miami Beach.

"More than 40 percent of the U.S. population lives in a coastal county," says Jack Cox, a coastal engineer, director of engineering for Edgewater Resources, and a professor of practice in civil and environmental engineering at UW-Madison. "As populations increase, this density increases and people's desire to be connected with the water, in some way, continues to grow. So, there's automatically a pressure to maximize the value (which can mean many different things to many different people) of our shorelines."

Knowing that people like to live near water, and will continue wanting to do so—even in the face of rising seas or, in regions like the Great Lakes, water depths that can swing from one extreme to another in a few short years—Cox says engineers must find ways to protect increasingly dense population centers from the very environment they desire.

Perspectives on how to do that, he says, have shifted over the last half century—from imposing seawalls to relying on "soft" defenses to now somewhere in between. Each extreme has come with

Dubai Palm Jumeirah island, United Arab Emirates.

Miami Beach inlet between Haulover and Bal Harbour.

Salvador da Bahia cityscape, Bahia, Brazil.

its own costs. Seawalls can be expensive and aesthetically displeasing, as well as disruptive to their natural environments. Soft defenses, such as extending sand beaches, can get expensive over time, as they require relatively constant upkeep as water washes away the sand. That washed-away sand also can have unintended consequences as the water deposits it elsewhere.

Beginning the 1970s and extending into the 1990s, coastal engineers moved toward using a mix of hard and soft structures. Forest Park Beach, located on Lake Michigan in Illinois, is an example of such defenses.

"That was built in the late 1980s," says Cox. "If you took a picture of it on that day and a picture of it today, it looks almost identical. It has not changed—and that's a positive."

Today, coastal engineers also are integrating human-designed soft structures to guide natural processes. The idea is working with nature, rather than against it.

"You introduce some sort of structure—it can be an underwater reef, a living breakwater, or any number of things—and place it so that the waves think the shoreline is different from what it is," says Cox. "As a result, you can better direct where the sand goes. It's all in the physics of understanding waves."

In New York City, for example, the East Side Coastal Resiliency Project aims to raise the East City River Park and implement buried coastal defense measures to protect land from ocean. Through the project, which is expected to be completed in time for the 2023 hurricane season, the city aims to thwart 100-year storms and the anticipated rise in sea levels by 2050.

"They've done three or four parks that have wetlands and soft-type solutions as the primary defense," says Fred Klancnik, a professor of practice in civil and environmental engineering at UW-Madison. "It takes more land, but they do it in a way so that they're engineering those protections, putting in hard structures and getting up to a higher elevation. Through sophisticated modeling and attention to detail, they're coming up with solutions that will stand the test of time."

Klancnik is an engineering veteran with nearly five decades of experience under his belt. The specific methods of engineering along shorelines have changed through the years, but he says the basics have remained steady since he graduated from UW-Madison in 1972.

Perhaps the greatest hurdle for coastal engineers is one they can't control: People like living near water—and that doesn't appear to be changing anytime soon.

In teaching the university's future generations of engineers, Klancnik challenges them to understand the history of their sites and how much water levels can vary, especially on lakes.

Daniel Wright, an assistant professor of civil and environmental engineering at UW-Madison, looks at trends in worsening storms across the United States. In July 2019, he published a study that found extreme storms in the lower 48 states are dumping more rain, and doing it more frequently than 50 years ago.

These storms threaten not only coastal communities, but those along rivers and lakes, which are engorged with floodwater as harsh storms increasingly and rapidly fill them. While an obvious way for citizens, businesses or communities to avoid such floods is to avoid building in these vulnerable areas, for established communities near water, Wright says there's a movement toward pulling the built environment away from riverbanks and adding green space as a buffer zone.

It's a change from old ways of thinking about using flood walls, which could funnel floodwaters downstream and make flooding worse.

"In the old days, we often used to build right up to the edge of the river," Wright says. "Now the idea is let's turn it into a park, which has multiple benefits. You're creating park land, which people like, but it also means there's room, when a flood comes, for the water to go into that park land without damaging any buildings."

Carolyn Voter, a now a postdoctoral scholar at UW-Madison, focused on green infrastructure as a graduate student in civil and environmental engineering. In urban areas, which can be particularly vulnerable to flooding because they're filled with impervious surfaces like streets, parking lots and sidewalks, there's a growing focus on methods such as rain barrels, rain gardens and other water detention practices.

However, urban soils also tend to be compacted, and that leads them to behave more like impervious surfaces and shunt water elsewhere, rather than absorb it. "It is pretty popular for people to disconnect their downspouts and let them spill out into their yard, but if the yard soil has been compromised, it can't absorb that water," she says.

"More than 40 percent of the U.S. population lives in a coastal county. As populations increase, this density increases and people's desire to be connected with the water, in some way, continues to grow."

— Jack Cox

And while grassroots efforts contribute to the solution, Voter says it's important for whole communities to adopt green infrastructure practices in order to make real changes. Many cities are still in the early stages, but some—Milwaukee, Philadelphia and Portland, Oregon, to name a few—are beginning to stand out as leaders.

"The power of the community is much stronger than what any individual person can do," she says.

Coastal engineers must also look at how small adjustments alter the big picture. Cox says it's crucial for communities to tackle these challenges together, from individual homeowners to governments, because nature works on a huge scale. For example, small walls here and there along a coast won't solve the problem of encroaching water. In fact, depending on the design and circumstances, it might make things worse in other areas.

"Mother Nature doesn't see an individual property," he says. "It sees miles of shoreline, and things that happen are happening on the scale of thousands of feet, or even miles. The challenge isn't just physically what you can do, but how you can do it on a broad enough level so that you actually can have a positive, meaningful impact."

Forest Park Beach, located on Lake Michigan in Illinois.

5 QUESTIONS WITH LINE ROALD ABOUT THE FUTURE OF OF THE POWER GRID

For most of the last decade, Line Roald has manipulated the levers of power—literally. A fellow in the Grainger Institute for Engineering and an assistant professor of electrical and computer engineering, Roald specializes in optimizing power grids to successfully integrate renewable energy like wind, solar and tidal energy.

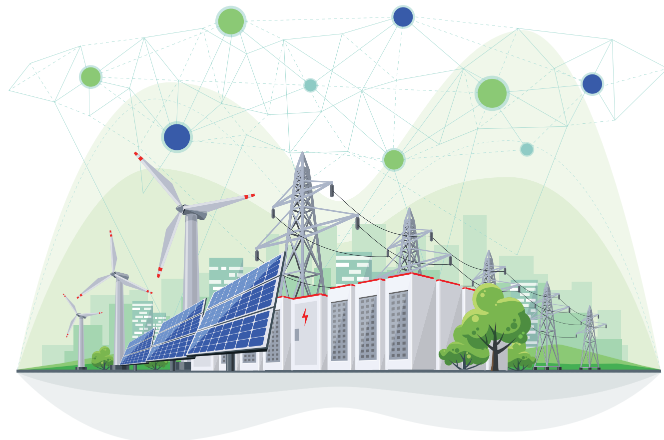
During her PhD work at ETH Zurich, she helped German grid operators figure out how to keep the lights on while they began a transition away from nuclear energy in favor of renewables. While a postdoc at Los Alamos National Laboratory, she investigated the best strategies for mixing green energy and legacy power sources, questions that she continues to pursue in Madison.

Many people no longer even notice the 240,000 miles of high-voltage power lines crisscrossing the United States or the 5.5 million miles of local distribution lines paralleling almost every street and highway. But that system of lines, power plants and substations is more than just a backdrop; it's an engineering marvel dubbed "the grid," delivering a seemingly endless supply of electricity to every outlet in the nation.

But after growing organically for almost 140 years, the grid needs some serious rethinking and a modern tune-up, especially as more renewable energy sources change the energy equation. We asked Roald what needs to happen in the near future to make the grid better.

1 What are the biggest problems with the current power grid?

One of the main challenges of electric power systems is making them greener and more sustainable, while remaining affordable and reliable. This means that we need to find secure and economic ways of integrating more renewable energy, but also that we must adapt to a changing climate with more extreme weather.



2 How can we make the grid more resilient and reliable right now?

We are aiming to develop analytical tools that will help us answer that question! One question we are trying to analyze in more detail is related to the wildfires in California in 2019, where the electric utility PG&E turned off power to millions of customers during high wind conditions to avoid electric faults that could ignite wildfires. We want to provide tools that enable better decisions in such challenging situations.

3 In 20 years, will we still need the traditional grid?

Yes, I believe that the electric grid will still be important in 20 years, but the role of the grid will change.

Renewable energy such as rooftop photovoltaic systems may allow more people to generate power where they live, and act as both consumers and producers of electricity. However, it is not necessarily sunny every time we want to use electricity. The grid is still useful because it connects many people and different sources of energy, which helps reduce the uncertainty and variability associated with renewable energy. It is also needed to bring energy from areas with a lot of sun and wind to areas where people live.

4 What solutions have you found for integrating more sustainable energy into the grid?

I have worked with electric grid operators to develop risk-based optimization methods that help them understand and manage the uncertainty and variability associated with renewable energy.

We develop risk-aware optimization methods, which help answer questions such as, "How should we dispatch traditional generators, renewable energy resources, and flexible loads to minimize the cost of electricity, while limiting the probability of transmission line overloads?"

By using more advanced methods for generation scheduling and risk assessment, the operators can make better use of the available renewable energy, which simultaneously lowers cost and increases reliability.

5 How do renewable energy sources change how the grid works?

Electricity is generated to always meet demand at any point in time. Traditional power plants that are fueled by coal or natural gas allow us to choose where and when we generate power.

Renewable energy sources, such as wind and solar, generate power when the wind is blowing or the sun is shining, and are therefore less controllable and predictable.

It also means that power is generated at different locations. On the one hand, we have local generation, such as rooftop solar, which typically serves the local load. On the other hand, we have large-scale projects such as big wind farms in windy regions, oftentimes in areas with low populatios density, such as Wyoming. The power generated by these wind farms is transported across large distances to reach big cities, and oftentimes requires investment in new transmission lines.

So, while we hear a lot about renewable energy and how it reduces the need for the grid, there is also the opposite side: A strong backbone grid is important to bring renewable energy from places with a lot of sun or wind to where people live.

A TALL ORDER

Research informs new standards for buildings made from wood

The 2021 International Building Code will contain new standards for using an engineered wood product known as cross-laminated timber in taller buildings than ever before.

They're standards informed, in large part, by research conducted by Laura Hasburgh, a technical staff member of the USDA Forest Service's Forest Products Laboratory (FPL) in Madison and a PhD student in materials science and engineering.

Essentially, Hasburgh researches how wood interacts with fire. At FPL, she studies the combustion of wood and engineered wood products in buildings, while as a graduate student, she examines the chemical, physical, structural and mechanical changes that take place when wood burns. For example, she has conducted extensive testing to determine the charring rates of six wood species—Douglas fir, southern yellow pine, redwood, black spruce, red oak and maple—commonly used as building materials. Char rates inform building code decisions about how to size wood structural members so that they maintain their strength in a fire long enough to give occupants time to exit or rescue personnel time to enter a burning building.

"Laura's graduate research has important practical implications for the design of modern buildings for fire safety, for the design of fire-safe wooden structures such as decks at the urban-wildland interface, and for the protection of firefighters who enter burning structures to save lives," says Don Stone, a professor of materials science and engineering and Hasburgh's advisor.

An engineered wood product made by gluing together perpendicular layers of solid-sawn lumber, cross-laminated timber is a sustainable, ultra-strong and aesthetically pleasing alternative to concrete and steel, which require massive amounts of energy to produce and transport.

Forest Products Laboratory researchers created five fire scenarios in a two-story, full-scale test building constructed using cross-laminated timber. *Photo: David Tucholski (ATF).*

This new understanding of how mass timber buildings perform during a fire convinced members of the Tall Wood Structures Committee to update the 2021 building code to reflect the ways in which it is possible to build safe, taller structures with engineered wood.

Laura Hasburgh has conducted extensive testing to determine the charring rates of six wood species, including black spruce.

Over the past two decades, this engineered timber has become increasingly popular in the United States as a structural material in "short" residential and commercial wood buildings, which are limited by building code to six stories.

The International Code Council develops the base construction and public safety code used in the United States as well as countries worldwide. Recognizing the potential of these advanced wood-based structural systems for much taller buildings, the council convened a Tall Wood Buildings Committee in 2015 to study the feasibility of and to take action on updating the code for wood structures taller than six stories.

"There's understandably a great deal of concern, especially when you take a combustible product and use it in a high-rise," said committee chair Stephen DiGiovanni in the October 2018 story, "Support for tall timber reaches new heights in building code," in *Architect* magazine. "As chair, I have to take as neutral an approach as possible, but if I leaned any way, it was to make sure the fire services issues were addressed."

Setting a series of test fires, Hasburgh and her FPL colleagues addressed those issues in a big way. In summer 2017, they conducted five large-scale fire experiments in a highly instrumented, fully furnished two-story apartment structure built with cross-laminated timber at the U.S. Alcohol, Tobacco, Firearms and Explosives Research Laboratory in Beltsville, Maryland.

The team varied the conditions for each test—from covering the wood with gypsum and exposing some of the walls or ceilings to adding sprinkler systems that responded immediately or experienced an intentional delay. From those tests, the researchers learned how much varying levels of exposed engineered wood contributed to the overall fire and how much charring damage, if any, the wood itself sustained. They also learned how the fire grew, spread and decayed, as well as how much heat it released, where that heat traveled throughout the structure, and how much time it took to extinguish the fire.

This new understanding of how mass timber buildings perform during a fire convinced members of the Tall Wood Structures Committee to update the 2021 building code to reflect the ways in which it is possible to build safe, taller structures with engineered wood.

Hasburgh's undergraduate degree is in architectural engineering and building construction and master's degree is in fire protection engineering, and she worked as a fire protection engineer and consultant before joining FPL and entering her PhD program at UW-Madison. She says a fire protection course she took as an undergraduate influenced the direction of her professional and academic careers. "It's a fun and innovative way to be at the forefront of the field," she says. "I enjoy the life safety and human aspect. Rather than applying building codes as a consultant, I'm now informing decisions about them."

GROWING A COLLABORATION THAT HONORS A TRADITION

The Ojibwe people tell of a prophecy that spurred their journey from the East Coast of the United States to the Great Lakes region more than 1,000 years ago. The revelations told them to travel west to a land where food grew on the water.

That food? Wild rice, or "manoomin" to the Native American nations that, like the Ojibwe, comprise the broader group of Anishinaabe tribes in the Upper Midwest and Canada.

But manoomin, which translates to "the good berry" in Ojibwe, is much more than just a crop to these tribes and others. It represents their connection to nature and holds profound spiritual significance as a gift from their creator. The Menominee Tribe's name literally means "wild rice people."

"It permeates all aspects of their cultures," says Sarah Dance, a member of the Lumbee Tribe of North Carolina and a second-year PhD student in civil and environmental engineering.

With funding from a UW-Madison Baldwin Wisconsin Idea Grant, she's working on a three-year project to build connections between the university and Native American tribes to protect and restore wild rice waterways, which have declined by a third since 1900. That's in part due to chemicals in the water and soil.

By testing water quality, studying sediment and conducting bucket experiments that will simulate a range of environmental conditions, Dance hopes to develop site-specific recommendations in partnership with her tribal collaborators from the Lac du Flambeau and Lac Courte Oreilles Tribes.

"Native people already know the water quality issues in the area that are impacting manoomin survival and growth, and the university has this wealth of resources that can look at some of those conditions," says Dance, who has worked on a wild rice outreach and education toolkit as part of a Wisconsin Sea Grant project. "We found that there are all of these diverse efforts out there to protect and restore manoomin across the region and they're not well-connected to one another. Our hope is that the research we're doing can push the needle forward on creating some best practices and sharing those across all those different entities."

Ultimately, she hopes to hand off leadership of the project to the tribes. William "Joe" Graveen, who's a wild rice technician in the Lac du Flambeau Tribe's wild rice cultural enhancement program, says he hopes the project will spur more research—at UW-Madison and other UW System schools—into the manoomin conditions in the state. "I think Sarah's project really is a good opportunity for the university to start building a better relationship, partnership with tribes," he says. "I think that's kind of the missing piece."

Dance also hopes to hire Native American students as summer interns, giving them the sort of experience she had working on environmental research with her own tribe as an undergraduate at North Carolina State.

And when she was weighing graduate schools, she looked for a place that would allow her to connect with Native American tribes on collaborative research. She's found that in Civil and Environmental Engineering Assistant Professor Matthew Ginder-Vogel's lab. "I'm hoping to spark an interest in pursuing science and to help improve Native American representation in STEM by creating this space for students to pursue research that aligns with their identity and what they want to do for their communities while also having the academic and rigorous aspects," she says. "You don't have to turn your back on your community or pursue something that doesn't align with your ideals."

BECOMING INTERNATIONALLY ELITE, FAST

In July 2019, 21 teams of students from around the world gathered in the California desert to find out whose designs for an ultrafast, airtight transportation pod would make the fastest trip down a mile-long test track during the fourth annual SpaceX Hyperloop competition.

Despite competition that included teams comprised of graduate students who worked on their pods full time as a focus of their research, our own Badgerloop—made up largely of undergraduates representing 20 majors across the university—impressed the judges with its ingenuity. In fact, Badgerloop has consistently been one of the top U.S. teams at the competition, taking home back-to-back innovation awards during the first two contests and being invited to make an additional presentation to SpaceX leadership for the past two years.

Participation in the competition is an invaluable opportunity for students to learn by doing, applying their skills and tenacity to realize their designs and then put the product through a real-world engineering review process. “One member ‘joked’ that he had learned more this week than throughout his entire academic career,” says Emma Krueger, who served as the team’s operations directory. “While that may not technically be true, our engineers and non-engineers alike learn and grow from experiences like this.”

In 2019, the rules of the competition were deceptively simple: The fastest hyperloop pod wins. But before teams could load their crafts into the mile-long, vacuum-sealed test track, they needed to complete a rigorous battery of tests, overseen by SpaceX experts. Ultimately, only four teams finished all the tests required to test their pods.

Although Badgerloop did not have the opportunity to see its pod in motion, the lessons the students learned will be invaluable as they look forward to the 2020 contest. Now team members not only are ready to tackle that challenge, but they also can apply their team experiences as they embark on varied academic and professional pursuits.

Learning as he grows

Engineering mechanics undergrad Mitchell Wall was among two UW-Madison students, and only 52 students nationwide, who earned scholarships from the Astronaut Scholarship Foundation in 2019. The foundation awards up to $10,000 in scholarships to outstanding junior and senior STEM students at partner schools across the United States.

Wall is interested in the aerospace field and, in addition to his academics, he fills his time with extracurricular activities ranging from the Badgerloop team to working as a co-op student with ATA Engineering at offices around the country.

Thanks to those experiences—particularly on Badgerloop—Wall has come to understand that making mistakes is part of the scientific process and he’s learned how to make improvements as he keeps pressing forward.

His “dream job” with ATA Engineering has allowed him access to groundbreaking engineering work, including NASA’s Mars 2020 rover project, and helped hone his skills with a variety of engineering analysis methods and tools. But he’s particularly proud of his undergraduate research contributions to real-world engineering challenges in Engineering Physics Professor Matt Allen’s group. Wall’s research focuses on predicting structural nonlinearities caused by bolted joints, and the group has developed a new method called quasi-static modal analysis (QSMA).

The group’s work has led to three paper publications, one of which Wall authored to present the first-ever comparison of experimental measurements to a predictive QSMA model.

Once he finishes his undergraduate degree, Wall says he plans to attend graduate school and continue his research, with a long-term goal of becoming a professor. “In doing so, I’ll use my teaching to pass on the passion and hard work that will fuel the next generation of students,” he says.

INDUSTRIOUS ENGINEER, SOCCER STANDOUT

Grace Douglas is a three-year starter at center back for the University of Wisconsin women's soccer team. "If I didn't play soccer at this level, I would have no clue how to push my limits like I do academically," she says. *Photo: Tom Lynn*

Captain of the nationally ranked University of Wisconsin women's soccer team. Double major in two challenging STEM fields. Undergraduate research assistant in an engineering lab. Data science intern in Washington, D.C.

There are times when Grace Douglas looks at her resume and worries it paints a picture of someone robotically collecting accolades, incessantly chasing achievement, leaving no space for enjoyment during her time at UW-Madison.

So she wants to clarify something. "I'm having the best time, I truly am," she says.

Douglas relishes her juggling act, balancing life as an industrial engineering and statistics double major with the demands of leading a perennial NCAA tournament qualifier. "She's one of these people who is sort of on a mission," says John Lee, the Emerson Electric Quality & Productivity Professor in industrial and systems engineering and one of Douglas' engineering mentors. "She has a clear idea of what she'd like to do, at least at a high level, and is very driven."

Douglas spent the summer of 2019 as a data science intern at ICR, a government contractor that specializes in work for the defense and intelligence communities. There, she drew on her coursework in the computer programming language Python to develop a neural network—a set of algorithms, essentially—capable of detecting anomalies in massive datasets.

The experience both stoked her interest in the national security field and validated her decision to add a statistics major in fall 2018 to enhance her technical prowess. "I'm a competitor," says Douglas, who landed the opportunity after connecting with alumnus Jerry Litzo (BSEE '99) at the College of Engineering's career fair. "Being on the cutting edge is something that intrigues me, and I think a national security job, especially in the intelligence community, gives me that. I also think national security is the most efficient way to help the most amount of people at a single time."

> ***"She has a clear Idea of what she'd like to do, at least at a high level, and is very driven."***
>
> ***— John Lee***

Summer is professional development time for Douglas, when she has a brief reprieve from the rigors of her soccer schedule. As a first-year student, she wanted to get research experience, so she went from office to office, looking for faculty who needed an undergraduate researcher. Lee did, and Douglas worked on a project examining the interactions between pedestrians and cars at intersections. Over the course of two summers, she captured video at four intersections around Madison, analyzed the recordings using coding software, and helped write the methods portion of the resulting paper in *Transportation Research Record*. "I think if you can learn to do research at that level—perform, relate and communicate your ideas at that level—you become loads smarter," she says.

Her smarts are also a major asset on the soccer field. As captain and a center back, the rangy redshirt junior organizes the Badgers' defensive shape, making sure they're clogging passing lanes and tracking opposing attackers.

After not playing a minute her first year—which turned into a redshirt season, giving her another year of eligibility—she's started every game over the past three seasons. "She didn't take the year off," says UW coach Paula Wilkins, who calls Douglas one of the best natural leaders she's coached. "She kept getting better and taking care of details. She took a lot of information in. A lot of people get emotional and don't hear information, but she had such a growth mindset; she would take the information, process it and get better."

Douglas has brought that type of rational thinking onto the field, whether she's interpreting tactical instructions from Wilkins and communicating them to teammates, spotting potential scoring threats or picking out the appropriate pass.

"It's hard to not get caught up in the emotion of a soccer game, because we have a bunch of very competitive women down to the core trying to win this game, and often we get selfish or frustrated or we're yelling at each other," she says. "I think it comes from the background that I have. I'm a STEM major, I like answers, I like solutions and how you get those answers. And that's the same thing on the soccer field. It just looks a little prettier."

WITH PERSEVERANCE, FIRST-GENERATION ENGINEERING STUDENT LANDS DEGREE, DREAM JOB

Finishing up at Verona Area High School, Will Carstens set out to pursue his dream of attending UW-Madison, being first in his family to earn a college degree, and becoming an engineer in the aerospace industry. That dream was nearly derailed by tragedy and hardships, but Carstens persevered.

UW-Madison was his top pick due to its highly respected and rigorous engineering programs.

"Growing up with a single mom, there wasn't money for college and I knew I would have to pay for school all by myself," he says. "So I figured I'd start off at Madison College to earn some credits and save money, then transfer to UW-Madison."

But soon after he began his first semester at Madison College in the fall of 2012, his mom was killed in a car crash with a drunken driver. The tragic loss sent Carstens reeling. "It was all a blur for me, and I was having a really hard time," he says. "I was an only child with a single mom, and with her gone, I had to grow up fast."

He dropped some classes, and then took the next semester off to regroup and earn money to support himself. He got a job working at a lumberyard full time, and then reenrolled at Madison College in September 2013, fitting classes in around his work schedule.

When he reenrolled at Madison College, he switched into the mechanical design technology program. As he neared completion of that two-year technical program, he considered giving up on his original goal of an engineering bachelor's degree given the challenges he was dealing with.

"But then I thought, I should keep pushing. I'm not going to give up on this," he says.

However, by taking time off from Madison College and switching his program, he was disqualified from the transfer blueprint program that he originally signed up for his first semester. That program would have guaranteed his admission to the UW-Madison mechanical engineering program so long as he stayed enrolled in the transfer program and held a cumulative 3.0 GPA.

Undeterred, Carstens dove into the application process for the UW-Madison College of Engineering. He was accepted into the mechanical engineering program at UW-Madison in September 2016.

In his first semester at UW-Madison, he joined the college's hybrid vehicle team (now the Wisconsin Formula SAE Autonomous Team). "Being on that team was a huge learning curve for me," he says. "It was amazing to see how talented and passionate the students on the team were, and how much they cared about what they were designing, and it inspired me to want to learn as much as I could from them."

His hands-on work with the team opened Carstens' eyes to the wealth of resources available for engineering students to design and build their own creations, including the makerspace and student shop facilities.

He took the initiative to learn how to use a variety of fabrication equipment, including laser cutters and 3D printers, and he found that these tools enhanced his understanding of concepts he was learning in class.

"I learn better when I can physically make something, feel it in my hands, and then actually test it, versus just reading about it in a textbook," he says. "I think one of the best things about UW-Madison is all of the opportunities that are available here, including many opportunities for engineering students to design and make stuff."

He says Engineering Career Services also played a crucial role in his success, giving him guidance on his resume and helping him land exciting internships and co-ops.

His co-op was at Collins Aerospace, one of the world's largest suppliers of advanced aerospace and defense products. "As I worked there, I learned so much about the industry past and future. It reinforced that I want to work in aerospace engineering," he says. "It also gave me some experience in what it's like to work as an engineer in industry, which was valuable."

Carstens graduated in December 2019 and began his career at Williams International, a small jet engine manufacturer located in Pontiac, Michigan.

COURSE OF ACTION

Machine learning comes to life

Graduate student Hanna Barton, left, shows Assistant Professor Justin Boutilier her work on a homework assignment for Machine Learning in Action. *Photo: Sarah Page.*

The language of machine learning was a decidedly foreign one to Hanna Barton.

A graduate student in industrial and systems engineering, Barton was among the first students to take the ISyE department's inaugural *Machine Learning in Action* course in fall 2019—and having taken only one course in the programming language Python as an undergraduate in biomedical engineering, Barton felt unnerved as Assistant Professor Justin Boutilier began the first lecture.

Eight weeks later, she found herself at the annual international meeting of the Human Factors and Ergonomics Society in Seattle, easily conversing with researchers who employ machine learning in their work. "It's probably the largest jump in my proficiency in a class," says Barton, who's studying human factors and health systems engineering.

In Machine Learning in Action, undergraduate and graduate students get an overview of popular machine learning methods—and then put them to work on real datasets, giving them a taste of the kind of work they're likely to find should they pursue careers in data science or, in the case of Barton and others, useful methods to apply in their own research.

Boutilier, who joined the College of Engineering in fall 2019, brought the course concept with him from the Massachusetts Institute of Technology, where he completed a postdoctoral research fellowship and taught a condensed version to master of business administration and master of supply chain management students in the Sloan School of Management.

Rather than concentrating heavily on the theory behind machine learning, Boutilier emphasizes tangible examples of problems that are ripe for solving with different methods. He introduces each technique with a case study, such as predicting the decisions of U.S. Supreme Court justices using decision trees or the crucial knowledge on cardiovascular disease that logistic regression has yielded from the landmark, longitudinal Framingham Heart Study.

> *"I hope it just shows students how these methods can actually be used in interesting problems, and that they know enough to go apply them."*
>
> *— Justin Boutilier*

Students try their hand at various methods—linear and logistic regression, clustering, classification, bagging, boosting and more—to ferret out insights from datasets that include life expectancies and potential contributing factors from all 50 states, rider data from the Boston bike share program and an assortment of information on plants related to the viability of invasive species.

By working through relevant questions using Python, the students get a firsthand look at the possibilities—and potential pitfalls—of machine learning and the level of rigor required to obtain accurate conclusions. "This course is focused on the application of machine learning," says Boutilier. "We don't really do a lot of theory. My goal for the students is that by the end of this course, they could go do this."

That's been the case for Ebrahim Eldamnhoury, a graduate student in the Department of Civil and Environmental Engineering's program in construction engineering and management. He's using methods from the course in his research trying to predict the likelihood of success of construction projects.

"I knew a little bit of machine learning, some preliminary stuff like linear or logistic regression," says Eldamnhoury, who's consulted Boutilier for advice on research dilemmas. "Getting into this class gave me a wide range of other tools that I can use in my research."

Boutilier also brings his own research on global health predicaments into the classroom. He's previously applied a technique called random forest—essentially myriad decision trees—to predict ambulance travel times in the populous and packed city of Dhaka, Bangladesh. And he's used a host of machine learning methods in his work predicting diabetes and hypertension risk in lower-income populations in India. "I hope it just shows students how these methods can actually be used in interesting problems, and that they know enough to go apply them," he says. "They basically know enough to do exactly what I did."

CHANGING LIVES

First-year engineers design cart for dog without front legs

University of Wisconsin-Madison first-year engineering students Jessica Nienhaus, Joshua Herche and Angela Bae work on their cart for Louie. The students were a group in the College of Engineering's freshman design course. *Photo: Sarah Page.*

In fall 2019, one team of students in the college's freshman design course had an unusual client: a frisky Nova Scotia duck trolling retriever mix named Louie. His owners, Madison residents Pat and Pete Sammataro, were hoping for a solution that would help Louie, who was born with no front legs, get out and about more easily.

The students modified an existing cart, adjusting it so that it can tilt forward to accommodate Louie's posture, and added small wheels for stability. They also added padding for comfort and presented Louie with a soft, calming vest to help him get used to the feeling of the cart around him. "This group of students has been wonderful," Pat says. "They came up with a design that's impressive and stable, and stability was a problem with the old one we had. Their design is amazing, and now it's up to us to work with Louie and get him used to it."

The design course offers first-year students from across the college the opportunity to learn engineering by doing it. Students in the class are split into teams to take on projects with real-world applications.

Team member Jessica Nienhaus, a biomedical engineering freshman whose interest is in prosthetics, says working with the team's furry and human furry client already has taught her to look at the bigger picture. "We had to think about biological things that go into it. For example, the way he's going to move because his back legs are higher—that's just natural to him," she says. "We also had to think a lot about overheating and his overall comfort. It's nice to be able to put all of that together with the engineering side of it."

THANKS TO ALUM'S CONTRIBUTIONS, APOLLO 11 MISSION: POSSIBLE

A half-century ago, Jyotindra (Joe) V. Mehta (MSME '64) watched the Apollo 11 landing from his small apartment in Clear Lake, Texas, with a vested interest in its success.

A NASA engineer, he worked on the simulator used to prepare Neil Armstrong for landing on the moon's surface.

As Mehta and his wife watched that landing on July 20, 1969, on their small black-and-white TV, he was moved by the enormity of the historic achievement. "That moment when Neil Armstrong landed, we were thrilled beyond words and jumping with joy," he recalls. "I felt an enormous amount of pride—not just for myself, but for the entire team that made that moment happen successfully."

Alumnus Joe Mehta holding the award plaque he received for his contributions to the Apollo 11 project.

"I am fortunate and grateful to have the opportunity to make a contribution to the iconic Apollo 11 mission. It's my legacy to my family and especially for my grandson."

— Joe Mehta

Mehta grew up in India and came to the United States to study engineering at UW-Madison. He says his graduate education played a crucial role in enabling him to contribute to the Apollo 11 mission.

"I am fortunate to have been educated by the superb engineering faculty at UW-Madison, especially my advisor, the late Professor Ronald Daggett, who designed an outstanding academic program for me that laid a strong foundation for my subsequent career path," he says. "It included courses in systems analysis, automatic controls, statistics and operations research, numerical analysis and Fortran programming, which were instrumental in developing the engineering and programming skills I would need in my career."

Mehta started his engineering career at Sperry Flight Systems in Phoenix, Arizona, where he developed software for aircraft and helicopter flight control systems and simulators. His skills were in high demand for the Apollo 11 mission, so he was transferred to the NASA Manned Spacecraft Center (now the Johnson Space Center) in Houston, Texas, to join a team dedicated to simulator complex (SIMCOM) labs.

From 1968 through 1969, he was an engineer on the Apollo 11 project, where he programmed computers that controlled simulators the astronauts used for training. Notably, he worked on the simulators that trained the astronauts on how to land the lunar module on the moon's surface. "This training was key to Armstrong manually controlling the lunar module during the last 1,000 feet when the automatic computer controlled landing was causing the lunar module to overshoot the landing site," he says.

He recalls the astronauts, who were not yet in the public eye, coming to his SIMCOM labs to do training runs. One of those astronauts was James Lovell, who was commander of the backup crew and capsule communicator for Apollo 11.

"I didn't know until later that (Lovell) is also a Badger!" Mehta says.

After NASA, Mehta joined IBM in 1978 and worked in software development and management. He advanced into senior technical and managerial positions at IBM before retiring in 2008.

While he's proud of the many successful products developed by his teams of engineers and programmers at IBM, Mehta says the experience of working on the Apollo 11 project as a 20-something engineer is tough to beat as a career highlight.

"I am fortunate and grateful to have the opportunity to make a contribution to the iconic Apollo 11 mission," says Mehta, who lives in Newport Coast, California. "It's my legacy to my family and especially for my grandson."

HONORING A COMMON PAST, PRESENT AND FUTURE

Roger Huibregtse (BSChE '50) speaks at a ceremony to dedicate the Huibregtse Family Commons on the first floor of Engineering Hall. *Photo: Todd Brown.*

"The Huibregtse family is proud to dedicate this collaborative space so others can learn, grow and create their own UW legacy."

Three generations of the Huibregtse family have studied engineering at the University of Wisconsin-Madison. So when family members began exploring opportunities to support the College of Engineering, they wanted to make a gift that would leave a lasting mark.

That idea came to fruition in summer 2019 with a ceremony to christen the atrium of Engineering Hall—a go-to spot for students to study, work on group projects, eat or relax between classes—the Huibregtse Family Commons. "The University of Wisconsin has been very important to our family. We've had six engineers that have graduated from UW, and we wanted to do something that would help future engineers in their studies," says Roger Huibregtse (BSChE '50), who started the family's UW-Madison legacy as the first of his kin to attend college. "I just wanted to give back something that they gave to me when they gave me a good education that allowed me to handle all the things that came before me."

He went on to become president and CEO of the Larsen Food Company, a subsidiary of Dean Foods, and has spent a good portion of his retirement volunteering through a nonprofit to help launch businesses in Eastern Europe. His late brother Richard (BSChE '57) followed his lead by studying chemical engineering at UW-Madison.

Roger's son Greg (BSCEE '72, MSCEE '74) is a civil engineer, while Greg's wife Kathryn (BSChE '74) is an adjunct professor in the Department of Civil and Environmental Engineering. One of Greg and Kathryn's sons, Brian (BSCEE '05), is a transportation and traffic team leader with MSA Professional Services in Madison. Another of Roger's grandsons, Kevin Fikkert (BSME '01) also graduated from the college and is president of Spindustries, a metal manufacturer in Lake Geneva, Wisconsin. "It prepared all of us for our lives after school," says Roger, who also supports the Huibregtse Family Scholarship for students interested in studying abroad.

Now, the family wants current and future students to experience that kind of success—a spirit summed up in one sentence of the naming plaque attached to a wall in the commons: "The Huibregtse family is proud to dedicate this collaborative space so others can learn, grow and create their own UW legacy."

CHANGING LIVES

A dozen alumni who make a difference

At the 2019 Engineers' Day banquet Oct. 11, 2019, the College of Engineering recognized 12 influential alumni who have applied their UW-Madison engineering education and experiences to make a difference in such fields as research, technology, business, government and more. Among the 12 are four young alumni who are exceptionally accomplished innovators and leaders.

Together, our award recipients illustrate the vast and remarkable impact Wisconsin engineers have in efforts that positively impact the lives of citizens around the world.

Global tech innovator Navrina Singh is among 12 alumni leaders we honored in 2019. *Photo: Todd Brown.*

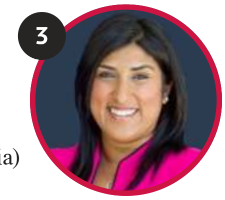
Early Career Award recipients

Amanda Engler
Experimental scientist, 3M
BSChE and Chem '05, UW-Madison
(MSChE '07, PhDChE '11, MIT)

A prolific researcher who already holds several patents, Amanda Engler is an expert in synthesizing materials for applications in medicine and biology. Among her many advances is a targeted system to deliver drugs that combat antibiotic-resistant fungi—the spread of which is becoming a serious global health threat. Throughout her career, Amanda also has been active in education, mentoring and service.

Christ Klündt
Co-Founder and CEO
StudyBlue/Flash Tools Chegg Inc.
BSBME '05, BSCS '05, UW-Madison

Chris Klündt is proof that life can take unexpected turns. He chose UW-Madison and majored in biomedical engineering in part because the university provided a path for him to enter medical school. Late in his undergraduate career, however, a very different door of opportunity opened, and he and a few friends developed an online peer-to-peer learning platform that today serves 20 million students.



Navrina Singh
Product and technology leader
MSECE '03, UW-Madison (BSEngr '01, College of Engineering at Pune, India; MBA '13, University of Southern California)

A leader in mobile technologies, Navrina Singh is known internationally as a global technology innovator. Working first at Qualcomm and later at Microsoft, she has helped pioneer mobile technology breakthroughs and leverage early artificial intelligence in virtual agents for enterprise customers. She also serves as a mentor, particularly in the startup community.

Nancy Spelsberg
President, BCP Transportation
BSIE '99, MBA '06, UW-Madison

When Nancy Spelsberg joined Alliant Energy, little did she realize that one of her positions—managing the company's distribution center—would prepare her to lead her own company in quite the way it did. She founded BCP Transportation with four trucks in 2011. Today, the company is a full-service transportation company, and it is known not only for the efficiency with which it moves goods across the country, but also for a company culture that puts people first.

5


Dan Adamany
Founder and CEO, AHEAD LLC
BSME ’97, UW-Madison

In the 12 years since Dan Adamany founded AHEAD, the company has provided customized information technology solutions to more than 500 enterprise clients. It has grown to 10 offices and three hundred employees, and is a tier-one advisor to many Fortune 500 and 1,000 companies.

6


Cynthia Bachmann
Vice president of engineering and product development, Kitchen and Bath Americas, Kohler Co.
BSEE ’83, UW-Madison

An early-career opportunity to be part of an integrated product team helped shape Cynthia Bachmann’s approach as a dynamic leader. As an executive with the Kohler Company, she has built and led teams across the globe and has driven a transformation that included creating a culture of innovation, and leading the Kohler Company’s evolution into more rigorous new product development.

7


Annie Caputo
Commissioner, U.S. Nuclear Regulatory Commission
BSNE ’96, UW-Madison

As a nuclear engineering student, Annie Caputo realized she could make the biggest impact on her field working not as an engineer, but in communication and public policy. Before being tapped to head the U.S. Nuclear Regulatory Commission, she spent nearly two decades as an advisor to both the U.S. House and Senate on topics that include nuclear energy regulation, policy development, legislation and communications.

8


Rodney Hassett
Vice president, treasurer and director (retired) Strand Associates Inc.
BSCE ’62, UW-Madison

After a short stint as a structural engineer in Chicago, Rod Hassett returned to Madison to join what then was a small engineering firm. During the next 40 years, his vision and leadership enabled Strand Associates to grow into a dynamic, multidisciplinary firm. Today, the company has 11 offices and projects in 48 states. Now, in retirement, Rod is a passionate mentor for engineering students, particularly those from traditionally underrepresented groups.

9


Mark Hoffmeyer
Senior technical staff member, IBM Systems
BSMetE ’83, MSMetE ’85, PhDMetE ’90, UW-Madison

IBM has a rich history of supercomputing dating back to the 1950s and today it boasts the world’s most powerful supercomputers. Mark Hoffmeyer joined the company until a few decades later and his technological advances have played a key role in enabling these computers to solve otherwise impossible problems.

10


Sunny H.K. Lo
Chairman, Café de Coral Holdings Ltd.
BSChE ’77, UW-Madison
(MSChE ’78, Stanford University)

When Sunny Lo decided to shift away from a career as a chemical engineer, many people questioned his decision. But after he returned to his native Hong Kong to help run his father’s small restaurant business, he leveraged his engineering training and problem-solving skills to implement innovative business practices. Today, Cafe de Coral has hundreds of locations throughout Hong Kong and southern China.

11


Duane Radtke
President and CEO, Valiant Exploration LLC
BSMineE ’71, UW-Madison

In a career that has spanned more than four decades, Duane Radtke has worked on energy production projects all over the world. In executive roles at of some of the nation’s largest energy companies, he has helped to supply power for millions of residential and commercial customers, and has been an advocate for new technologies in the oil and gas industry.

12


Thomas Werner
Chairman and CEO, SunPower Corp.
BSIE ’82, UW-Madison (BSEE ’86, Marquette University; MBA ’95, George Washington University)

On the front lines of the solar revolution, Tom Werner is helping to drive the disruption taking place across the global energy industry. His company, SunPower, has offices on five continents, holds more than a 1,000 patents for solar technology, and produces some of the world’s highest-efficiency solar panels for homeowners and businesses.

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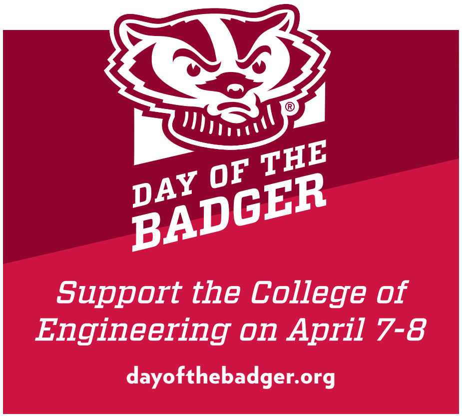
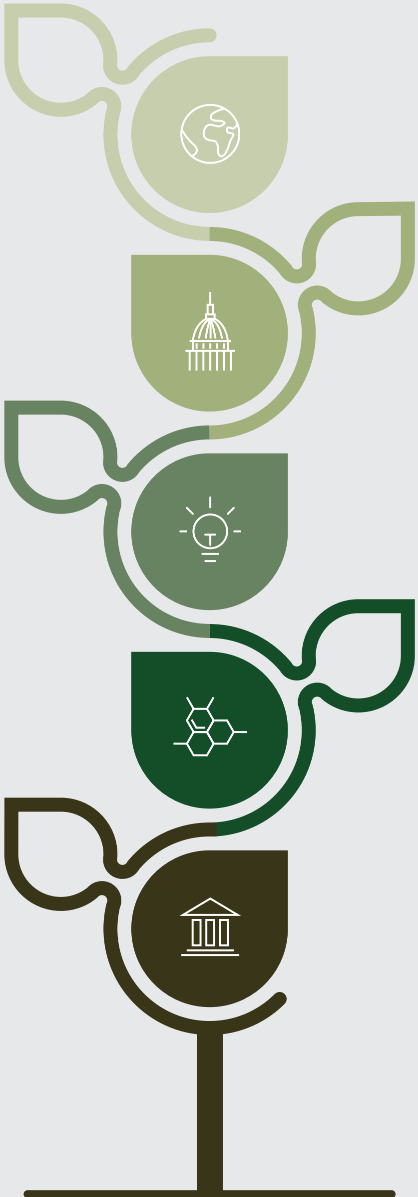


ENGINEERING **IMPACT**



The College of Engineering is a thriving, top-ranked college within Wisconsin's flagship university. Building on a heritage of impact, we work together to develop the leaders, knowledge and technologies that improve lives now and create a better future.

Building on a tradition of success:

- Engineering academic programs consistently ranked in top 20
- UW-Madison ranked #13 of 140 U.S. public universities
- College research expenditures are nearly $100 million annually
- UW-Madison ranked #8 nationally in research expenditures

Developing generations of engineering leaders:

- With 6,000 undergraduate and graduate students total, engineering is the 2nd largest college at UW-Madison
- 4,500 undergraduate students; 1,000 graduates annually
- 15 new accelerated master's programs focus students' expertise
- 1,500 graduate students; 420 graduates annually
- 3,700 employers recruit our engineers annually
- 45,000 alumni worldwide

Extending our impact:

- Our faculty, staff and students disclose more than 100 inventions annually
- Engineering research has spun off in dozens of companies such as TomoTherapy, Virent and Shine Medical Technologies
- 40 engineering research centers, institutes and consortia collaborate with hundreds of industry partners annually
- UW-Madison ranked #20 internationally in the PitchBook's Top Universities for VC-backed Entrepreneurs