

# PERSPECTIVE

## BUILDING CONNECTIONS

EVERYDAY  
AI

ASPHALT  
REIMAGINED

BIOFUEL FOR  
THOUGHT

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College of Engineering  
UNIVERSITY OF WISCONSIN-MADISON

# PERSPECTIVE MAGAZINE

## ENGINEERING EXTERNAL RELATIONS

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### Keep up with the college

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# GREETINGS FROM MADISON!

## Dear engineering alumni and friends:

You may have heard about the partnership UW-Madison established with Foxconn Technology Group a few months ago. Through its agreement with the university, the company plans to invest \$100 million in engineering and innovation research at UW-Madison. The investment creates a framework for collaborations, and it also includes funding to help construct an interdisciplinary research building for our college.

While this partnership certainly is an exciting opportunity that garnered quite a bit of attention after we announced it in August 2018, it's also one of many collaborations we maintain with our industry partners. Engagement with industry is important—to our faculty, staff and students, as well as the companies we partner with—for a number of reasons.

For example, industry increasingly relies on universities for advances in basic research—and these advances can enable companies to focus on applied research for product development, and ultimately bring new technologies to market more quickly.

When our faculty, staff and students collaborate with researchers from industry, they also learn about industry challenges, needs and trends. That knowledge can provide context for our students' education, help inform our research directions, and create opportunities and experiences that better prepare our students to be leaders as they graduate and enter the workforce. One highly successful example of this approach is our Wisconsin Electric Machines and Power Electronics Consortium. Founded in 1981, the consortium now has the support of more than 80 companies and over time, its faculty, staff and hundreds of graduate and undergraduate students have generated pioneering advances in numerous areas of electric and advanced machines, power conversion, and controls and sensor technology.

Aside from research consortia, many companies undertake focused research projects with individual faculty members or with interdisciplinary teams of faculty, staff and students. These interactions also allow us to share our knowledge and expertise in ways that address specific company challenges. A new public-private partnership master agreement plan developed recently through our Grainger Institute for Engineering also will facilitate industry engagement with our faculty.

Industry interaction with our college also can help to enhance our students' educational experiences. In some cases, our corporate partners choose to provide funding for facilities—recent examples include the Plexus Collaboratory and the Qualcomm Design Laboratory in electrical and computer engineering, the Sub Zero Design Lab in mechanical engineering, the Kohler Innovation Visualization Studio in our makerspace, and the Rockwell Automation Industrial Connected Enterprise Laboratory in the Engineering Centers Building. You can read about the Rockwell facility on page 25.

Companies also interact directly with our students. Many of our departments offer design courses in which students collaborate with a company “client” to tackle a real challenge. Not only do these experiences enable our students to draw on their body of engineering knowledge and work in teams to solve problems, they also provide students a view of their future as engineering professionals. Similarly, companies who participate in our Employer Partner Program can initiate a student design project through a department or cross-disciplinary course; host a day on campus that provides students an in-depth perspective on their values, culture, products and work environment; or provide financial support in areas such as diversity, student organizations and scholarships.

In diverse ways, all of the initiatives I've just described support our mission to provide the best education to our students so that when they graduate, they can leverage their UW-Madison engineering experiences and make a difference in our world. So most importantly, our outstanding Engineering Career Services staff work annually with 1,300 employers who seek to add our engineers to their companies through internships, co-operative experiences, and full-time employment. That's a win for everyone.

## ON, WISCONSIN!



Dean Ian Robertson, UW-Madison College of Engineering



## IT'S NOT A SHOCK

### Better bandage promotes powerful healing



Photo: Sam Milion-Weaver

A new, low-cost wound dressing could dramatically speed up healing in a surprising way.

The method leverages the energy generated from a patient's own natural body motions to apply gentle electrical pulses at the site of an injury. In rodent tests, the dressings slashed healing times from roughly two weeks (for untreated injuries) to a mere three days.

Electricity can be beneficial for skin healing, but most electrotherapy units in use today require bulky electrical equipment and complicated wiring to deliver powerful jolts of electricity.

The new dressing is much more straightforward. "Our device is as convenient as a bandage you put on your skin," says Materials Science and Engineering Professor Xudong Wang.

It consists of small electrodes for the injury site that are linked to a band holding energy-harvesting units called nanogenerators, which are looped around a wearer's torso. The natural expansion and contraction of the wearer's ribcage during breathing powers the nanogenerators, which deliver low-intensity electric pulses.

Those pulses encourage skin cells called fibroblasts to line up—a crucial step in wound healing—and to produce more growth factors.

Now, Wang and his collaborators are studying how the gentle pulses aid in healing. They will test the dressing on pig skin, which closely mimics human tissue. They also will refine the nanogenerators to harvest energy from even tinier movements such as twitches in the skin.

The devices could help solve a major challenge for modern medicine. "We think our nanogenerator could be the most effective electrical stimulation approach for many therapeutic purposes," says Wang.

And because the nanogenerators consist of relatively common materials, price won't be an issue: "I don't think the cost will be much more than a regular bandage," he says. "The device in itself is very simple and convenient to fabricate."



Materials Science and Engineering Professor Xudong Wang fits a new wound dressing around the wrist of graduate student Yin Long. The device stimulates healing using electricity generated from the body's natural motions.  
Photo: Xudong Wang.

# PRESERVING NUCLEAR FOR THE NEXT GENERATION

Molten salt nuclear reactors are under development by startup companies across the world as a promising next-generation technology—and UW-Madison engineers support this development by advancing molten salt science and technology.

“To be viable, these future reactors must be more economical and potentially more efficient than current nuclear power technologies that have changed little in decades, while fulfilling the safety requirements of the U.S. Nuclear Regulatory Commission,” says Engineering Physics Assistant Professor Adrien Couet, who researches environmental degradation of nuclear materials. “There needs to be innovation. We need to change how we build nuclear power plants and we need better technologies to compete with other power sources.”

To that end, Couet and Distinguished Research Professor Kumar Sridharan are part of a multi-institution team in the middle of a \$3 million, three-year DOE funded research project called Nuclear Science Technology and Education for Molten Salt Reactors, or NuSTEM.

Together with colleagues at Texas A&M and UC-Berkeley, faculty, staff and students in Madison already are making progress. For example, Couet, Sridharan and colleagues are investigating how structural materials corrode in nuclear reactors. The NuSTEM project is also striving to establish active educational collaborations with SAMOFAR, a consortium of molten salt educational and research institutions in Europe, to provide a platform for exchange of young students and scientists.

“They’re doing great work,” says NuSTEM advisory board chairperson Warren Miller, who is retired from the Los Alamos National Laboratory and was assistant secretary of energy for nuclear energy under former U.S. President Barack Obama. “What these universities are doing—pushing the frontier to develop real-life tools to help in the design of molten salt reactors—is very important, and they’re making real progress.”

*UW-Madison engineers are making advances to help usher in next-generation molten salt nuclear reactors*



## TECH TEAMUP COULD TURBOCHARGE ELECTRICITY GENERATION



In the future, an internal combustion engine similar to the one in your car might also play a key role in generating electricity more efficiently.

Currently, most of the electricity fed into the power grid is generated by large fossil-fuel-burning power plants. They're only about 36-percent efficient, however—and, by the time the electricity reaches a power outlet in your home, energy losses in transmission drop the efficiency to 34 percent.

Instead, by integrating an internal combustion engine and a solid oxide fuel cell into a hybrid system that capitalizes on the unique characteristics of each, Mechanical Engineering Assistant Professor Sage Kokjohn aims to double that efficiency.

Fuel cells generate power through an electrochemical process, and certain types of fuel cells can use natural gas as fuel to generate electricity. When everything's said and done, however, they consume only about 75 percent of the fuel's energy, and the remaining energy in the exhaust that leaves the fuel cell is wasted.



That's where Kokjohn sees an opportunity to put the unused fuel to work.

His hybrid system will direct the fuel cell exhaust into a souped-up advanced compression ignition engine, allowing the engine to generate additional power from the fuel cell's leftovers. It also provides the system the ability to easily adjust to shifting power demands—particularly as more renewable, and highly variable, energy sources like wind and solar are added to the grid.

**More:** [www.engr.wisc.edu/new-generation-unique-technology-turbocharge-electrical-efficiency/](http://www.engr.wisc.edu/new-generation-unique-technology-turbocharge-electrical-efficiency/)



## GAINING AN ADVANTAGE OVER ADVERSE EVENTS

An aerial view of the houses in a village destroyed by a tropical storm.  
Photo: Marco Dormino / United Nations.

*A flood is approaching. Relief organizations and local volunteers frantically start sandbagging the area. The effort helps, but most of the work happens after disaster strikes.*

Floods, landslides, earthquakes, severe storms: Natural disasters tend not to give much warning of their arrival, leaving relief organizations scrambling—after the fact—for the right ways to help.

Paul Block is working to take some of the guesswork out of preparing for the next disaster.

The assistant professor of civil and environmental engineering and his collaborators are developing an online flood and health risk management system. The system is centered on the ability to predict next season's rainfall by evaluating large-scale climate and land surface characteristics. It's targeted at relief agencies and government organizations.

He hopes the system will save lives by improving existing disaster management practices so that those organizations have months—not hours or days—to prepare for disasters.

"We are aiming to establish frameworks for organizations so they may determine if and when they should take action and what course of action should that be," Block says. "We are specifically addressing flood disasters, but such frameworks may be broadly applicable to disaster preparedness in general."

**More:** [www.engr.wisc.edu/paul-block-works-develop-proactive-disaster-early-warning-system/](http://www.engr.wisc.edu/paul-block-works-develop-proactive-disaster-early-warning-system/)



Paul Block is developing an online flood and health risk management system in an attempt to give relief organizations months—not hours or days—to prepare for disasters. Photo: JC McIlwaine / United Nations.

## MEET OUR NEW FACULTY

In 2018, our college welcomed a dozen outstanding faculty who contribute their passion for educating our students and their expertise in areas including health, the environment, materials, energy, optimization, and more.

### BME

#### Associate Professor Kip Ludwig

Working within the world of neural engineering, he's developing small, smart devices for the next generation of personalized precision medicine. Ludwig also is neuroengineering lead in the Grainger Institute for Engineering.

**More:** [www.engr.wisc.edu/focus-new-faculty-ludwig-hijacks-nervous-system/](http://www.engr.wisc.edu/focus-new-faculty-ludwig-hijacks-nervous-system/)



### ECE

#### Assistant Professor Bhuvana Krishnaswamy

Applying the theories and algorithms of traditional wireless networks, she aims to create living sensors from networks of bacterial cells.

**More:** [www.engr.wisc.edu/focus-new-faculty-bhuvana-krishnaswamy-brings-biology-electrical-engineering/](http://www.engr.wisc.edu/focus-new-faculty-bhuvana-krishnaswamy-brings-biology-electrical-engineering/)



#### Assistant Professor Line Roald

Drawing from the field of optimization, she's rethinking how electricity from renewable sources can flow reliably through the grid and into our homes and businesses. She also is part of the energy and sustainability group in the Grainger Institute for Engineering.

**More:** [www.engr.wisc.edu/focus-new-faculty-line-roald-reshaping-power-grid-renewable-energy-future/](http://www.engr.wisc.edu/focus-new-faculty-line-roald-reshaping-power-grid-renewable-energy-future/)



#### Assistant Professor Joshua San Miguel

Highly regarded in the fast-growing field of approximate computing, he aims to give programs leeway to sometimes deliver inaccurate results in return for huge gains in efficiency and energy savings.

**More:** [www.engr.wisc.edu/focus-new-faculty-joshua-san-miguel-teaches-computers-read-bits/](http://www.engr.wisc.edu/focus-new-faculty-joshua-san-miguel-teaches-computers-read-bits/)



### CEE

#### Assistant Professor Hannah Blum

Adding strong expertise to our growing structures group, she uses experimentation and modeling to analyze the performance of steel.

**More:** [www.engr.wisc.edu/focus-new-faculty-blum-comes-land/](http://www.engr.wisc.edu/focus-new-faculty-blum-comes-land/)



#### Assistant Professor Nimish Pujara

Studying how turbulent flows behave in the real world, he hopes to inform how we develop, manage and protect coastal areas.

**More:** [www.engr.wisc.edu/focus-new-faculty-pujara-goes-flow/](http://www.engr.wisc.edu/focus-new-faculty-pujara-goes-flow/)



#### Assistant Professor Bu Wang

Focusing on sustainable materials, he is researching everything from glass and concrete to next-generation batteries and ceramics for fuel cells. He also is part of the energy and sustainability group in the Grainger Institute for Engineering.

**More:** [www.engr.wisc.edu/focus-new-faculty-bu-wang-studying-materials-safer-sustainable-world/](http://www.engr.wisc.edu/focus-new-faculty-bu-wang-studying-materials-safer-sustainable-world/)



### EP

#### Assistant Professor Jennifer Franck

Applying new computational methods to real challenges in energy, she aims to better understand unsteady fluid flows, and as a result, improve existing systems and advance state-of-the-art technologies.

**More:** [www.engr.wisc.edu/focus-new-faculty-jennifer-franck-modeling-complicated-flows-improve-energy-systems/](http://www.engr.wisc.edu/focus-new-faculty-jennifer-franck-modeling-complicated-flows-improve-energy-systems/)





## ISyE

### Assistant Professor Carla Michini

Examining the structures of complex problems, she's identifying efficient algorithms that yield optimal solutions.

**More:** [www.engr.wisc.edu/focus-new-faculty-michini-finds-optimal-home-isye/](http://www.engr.wisc.edu/focus-new-faculty-michini-finds-optimal-home-isye/)



## ME

### Assistant Professor Mark Anderson

Tackling energy-related challenges from a number of angles, he aims to improve power plant efficiency.

**More:** [www.engr.wisc.edu/revving-power-plant-performance/](http://www.engr.wisc.edu/revving-power-plant-performance/)



### Associate Professor Christian Franck

Aiming to inform guidelines and medical protocols for traumatic brain injuries, Franck studies how the physical forces of an impact can cause trauma in the brain and lead to cell loss.

**More:** [www.engr.wisc.edu/focus-new-faculty-christian-franck-studies-cell-stress-strain-damage-brain/](http://www.engr.wisc.edu/focus-new-faculty-christian-franck-studies-cell-stress-strain-damage-brain/)



### Assistant Professor Stephan Rudykh

Often taking inspiration from nature, he's developing new design rules for tailoring the microstructure of materials—particularly soft materials such as human tissue.

**More:** [www.engr.wisc.edu/focus-new-faculty-stephan-rudykh-developing-design-rules-fine-tuned-materials/](http://www.engr.wisc.edu/focus-new-faculty-stephan-rudykh-developing-design-rules-fine-tuned-materials/)



## SMALL INVESTMENT, BIG RETURN

When you partner with the College of Engineering, you're not just investing in the future of your company—you're helping the next generation of Badger engineers who will improve our world.

We are excited that the following companies have joined our Employer Partner Program—and we'd like to add your company, too. The program offers your company a variety of opportunities to increase its visibility among our students, interact more closely with students, and help shape our students' experience.

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### Join the College of Engineering Employer Partner Program today!

To learn more about the myriad ways your company can connect with our college, contact Justin Hines at [jhines3@wisc.edu](mailto:jhines3@wisc.edu) or (608) 262-0578.

**Interesting in learning more?** [go.wisc.edu/coe-corporate](http://go.wisc.edu/coe-corporate)



# *DRIVING INNOVATION*

by Sam Million-Weaver



# *Can biofuels transform our economy?*

## **America is a car country.**

Drive-in movies, drive-through restaurants, road-trips, carpools: Our culture is full of odes to our automobiles.

And even though people are increasingly trading in their gas-guzzling pink Cadillacs for more efficient hybrid and electric vehicles, our infatuation with our cars means that the United States has an insatiable thirst for fuel, burning through nearly 400 million gallons of gasoline every day, according to estimates from the U.S. Energy Information Administration.

“We all continuously consume fuels,” says Christos Maravelias, the Vilas Distinguished Achievement Professor and Paul A. Elfers Professor in chemical and biological engineering and an expert in chemical production planning and process optimization. “Even when we’re not driving, we need heating or we use products that were transported from elsewhere.”

It’s a lot of fuel. For the most part, it’s fuel that still comes from refined crude oil.

And, for multiple reasons, including the health of our planet and an imperative to reduce our country’s reliance on foreign oil, the United States will need to cut back on its use of fossil fuels.

One option that for the past decade has shown promise is the idea of swapping out oil for biofuels made from plants or bacteria and algae.

The United States is sitting on a resource of almost 1.5 billion tons of biomass that could go toward biofuels each year. That’s the energetic equivalent of 4 billion barrels of oil, and given that America uses 6 billion barrels of oil annually, biofuels could make a massive dent in our petroleum consumption.

“We have an amazing opportunity to displace a very large fraction of the transportation economy,” says Brian Pfleger, the Jay and Cynthia Ihlenfeld Professor in chemical and biological engineering and an expert in synthetic biology for harnessing microbes to produce useful products.

## The root of the challenge

That sounds great, in theory—but let's put on the brakes for a moment.

Not all biofuels are created equal.

There are three commonly accepted classes of biofuels, distinguished by the source of organic material, or "feedstock," from which they are derived.

The so-called "first-generation" biofuels make use of sugar derived directly from food crops like corn, wheat or sugarcane. Second-generation biofuels rely on plant material that's unfit for human consumption. These include materials like wood waste, corn stalks or a poisonous weedy bush called *jatropha*. Third-generation biofuels are made from microbes, like algae.

Perhaps the most well known first-generation biofuel is ethanol, and it's also the most commonly produced in the United States. In fact, making sugar into fuel is pretty easy: Ethanol production takes advantage of the same chemical reactions that give humans alcoholic beverages. Yeast happily gobble glucose and produce ethanol as a waste product.

There are problems, though. For one, using crops like corn for fuel drives up food costs. And, ethanol absorbs water, which can cause engine damage. Finally, one gallon of ethanol will only get you two-thirds the distance as the same amount of gas; in fact, its lower energy content is one reason ethanol is almost always blended with conventional fuel.

"We're not interested in ethanol," says systems biology expert Jennifer Reed, the Harvey D. Spangler Faculty Scholar and a professor in chemical and biological engineering, who analyzes the chemical reactions living things perform to reveal new synthesis pathways. "The next stage is to move beyond ethanol and look at higher-energy-density fuels, and things that are compatible with modern engines."

## A crude awakening

In a way, a turn toward biofuels would represent a return to earlier times.

Before we struck oil, much of our country's energy needs came from coal and

our fuel largely originated from biological sources. Rudolph Diesel, inventor of the eponymous engine, envisioned pure peanut oil as a fuel source for his contraption at the turn of the 19<sup>th</sup> century.

But when the country discovered crude oil in the mid-1800s, cheap fossil fuels took over.

That means biofuels need to compete with an industry that has a 150-year head-start. And fossil fuels are incredibly cheap.

"Fuels are a low-value product produced with an established, well integrated existing infrastructure," says George Huber, the Richard L. Antoine Professor in chemical and biological engineering and an expert in catalysis for converting plant material to biofuels and biochemicals. "The average refinery makes three to five cents of profit per gallon of gasoline."

Those refineries sell billions of gallons of gasoline every year. That dwarfs the output of most biofuel plants while also undercutting them, cost-wise.

"Being able to make bioproducts at a price that is compatible with current oil refining processes is the biggest challenge for the field," says Reed. "There are a number of technical challenges, including the upstream processes in producing the actual fuels, and then downstream processes to separate out the useful products."

One factor in keeping fossil fuel prices low is that engineers have found ways to extract useful products from almost every last drop of crude oil.

"Almost nothing is as efficient as a petrochemical refinery," says Pfleger. "There's been more than 100 years of optimization. This is why our field was created."

In other words, crude oil doesn't just become the gas in our tanks, but a whole

host of chemicals and petroleum-derived products we use every day.

"We are surrounded by various materials made from petroleum derivatives," says Pfleger. "There are places that might be replaced by bio-sourced materials, but any new material would need to be functionally equivalent and less expensive. Right now, this class of petroleum-derived molecules is very cheap."

One important petroleum-derived molecule is the chemical benzene, which is used to manufacture several different plastics such as polystyrene, polycarbonate and nylon.

Among many other uses, polystyrene is the plastic that becomes disposable silverware and Styrofoam packaging. Polycarbonate's durability and transparency makes it ideal for such applications as the barrier windows in banks.

The world used more than 53 million tons of benzene in 2018, and forecasts indicate market demand will steadily increase.

Benzene is one of three chemicals in a mixture called BTX, which petroleum refineries produce from crude oil through a process called catalytic reforming. The other compounds in BTX—toluene and xylene—also go toward plastics and resins like polyurethane and polyester.

Plastics aren't the only products that keep the price of fuel low. Other compounds left over from the refining process form the foundation for cosmetics and pharmaceuticals.

All this means that fossil fuels have a very firm foothold in the U.S. economy—and if they are to compete, biofuels will need to diversify to accommodate our demand for plastics, perfumes and prescription drugs.



That's why some biofuels researchers are shifting their focus away from gasoline and instead are focusing on bio-based alternatives to some of the chemicals that currently come from crude oil.

"Displacing some expensive chemicals might be easier, from an economic standpoint, than producing fuels in a small biorefinery," says Maravelias. "There's an interesting trade off, though: We want to replace commodity chemicals, but commodity chemicals are cheap."

## Carbon copying

So what is the best way to leverage all of our biomass? Do we focus on fuel? Synthesize bespoke compounds? Or take aim at cheap commodity chemicals?

It's a question of carbon.

Carbon is currency for petroleum products and biofuels.

Crude oil contains a mix of molecules called hydrocarbons, which are made up of multiple carbon atoms linked together in long, branching or looped chains and decorated with hydrogens. The explosive combustion reaction inside an engine's piston happens when those hydrocarbons combine with oxygen to form carbon dioxide, water and heat.

Longer hydrocarbons yield more energy. Petroleum-derived gasoline is usually a blend of molecules containing four to 12 carbons. Jet fuel is typically stronger stuff, with lengthier hydrocarbon chains. Compounds with five to seven carbons are known as naphthanes, which are often used as solvents or dry-cleaning chemicals; ethylene, a plastic precursor, is a tiny two-carbon molecule.

Living things on Earth happen to be carbon-based, which is why we can extract hydrocarbons from the sugars and fats that form components of cells. In fact, fossil fuels are the remains of formerly living organisms, transformed into pure hydrocarbons after spending millions of years buried deep underground and subjected to intense pressure and heat.

However, today's freshly harvested plants or microbes—biofuel feedstocks—are much more complicated.

For one thing, living things like plants and algae contain enormous amounts of water. Even "dry" biomass contains as much as 50 percent water by weight.

Additionally, the carbon in biofuel feedstocks is locked into complicated sugar and fat molecules. That's one reason the GVL solvent developed by James Dumesic, the Ernest Micek Distinguished Chair in chemical and biological engineering and a world expert in the chemistry of converting plant material into useful fuels, chemicals and solvents, made such a big splash in 2008. His straightforward process breaks plant material into useful feedstock streams.

Even broken apart, sugars from plants always contain additional atoms from substances such as oxygen that are not normally found in petroleum products.

Those oxygens might be biomass' secret weapon, though. Some high-value chemicals like drug precursors or artificial flavors also contain oxygen, meaning that it may be advantageous to make these products from biomass.

"In some cases, going from biomass to chemicals is cheaper and easier than using petroleum because you're starting with something that's closer to the end product," says Kevin Barnett, a postdoctoral scholar in chemical and biological engineering and an entrepreneur in the bio-based chemicals industry.

Barnett identified one such high-value chemical, a component of paints and coatings called 1,5-pentanediol, during his graduate work with Huber. 1,5-pentanediol can be made alongside ethanol in a biofuel refinery. The process Barnett helped develop produces 1,5-pentanediol at such a low cost that it has the potential to drive ethanol prices down by \$2 per gallon.

Working with the Wisconsin Alumni Research Foundation, Barnett spun the discovery into a company, Pyran, and he's in the process of securing additional funding to grow the business.

Pyran follows in the footsteps of multiple successful bioproduct spinoffs from UW-Madison, perhaps most famously the pioneering example set by Doug Cameron, a professor of chemical and biological engineering from 1986 to 1998.

Cameron found a biological synthesis pathway for the compound 1,3-propanediol, which is now sold as Susterra and woven into a vast array of synthetic fabrics and carpets thanks to its superior stretchiness, soft feel and ability to take up dye.

Another spinoff, Virent, had its origins in the lab of Dumesic. The company uses patented chemistry to turn biomass-derived sugars into a variety of products, including plastics, diesel and jet fuel. Virent was acquired by the oil refining company Tesoro, and its success stories include a partnership with Coca-Cola to develop plant-based soda bottles and a low-soot bio-based jet fuel.

## Sky-high hopes

So, what's coming down the road?

Chemicals are one promising sector where biofuels could make a dent. Jet fuel is another. But cars probably won't drive the biofuel economy.

"In the next 20 years, the demand for gasoline is projected to peak and then start decreasing," says Huber. "The largest demand increase is going to be in fuels for heavy-duty vehicles and in aviation, which are primarily diesel and jet fuel."

Biofuels are already making inroads in the aviation industry. In 2016, Jet Blue announced a record-setting 10-year deal to purchase 330 million gallons of renewable jet fuel. Singapore Airlines began running nonstop biofuel-powered flights from Singapore to San Francisco in 2017.

Back on Earth, bio-derived chemicals are slowly but surely making inroads in consumer products. While that progress might seem slow compared with the breakneck pace of electronic technology innovation, researchers today—including experts in the College of Engineering—are addressing the real-world basic science questions to unlock the full potential of biofuels for the future.

"We have a resource; we have a demand," says Pfleger. "The question is, how can we move forward?"

# The road to greener asphalt

by Tom Ziemer

**Asphalt covers more than 90 percent of the 2.7 million miles of paved roads in the United States.**

It's a durable yet flexible material, creating smooth pavement for our traveling convenience. But the steady pounding of semi trucks, the yearly squeeze and release of the freezing and thawing cycles, the heat of the sun's rays, and the effects of constant oxidation eventually win out.

Asphalt will break down—and when it does, we rip up our roads and start over.

But the asphalt rubble we see piled alongside the highway during road construction season isn't simply junk to be discarded. With a little rehabilitation, it can regain its flexibility and thus, its usefulness—and thanks to environmental, logistical and financial motivations, there's growing interest in putting more recycled asphalt back on the road.

"This is the new frontier," says Hussain Bahia, the Vilas Distinguished Professor of civil and environmental engineering and an internationally sought-after expert on asphalt.

## Reusable, in theory

Humans have used asphalt since ancient times, hence the rug on the floor of Bahia's Engineering Hall office depicting the Babylonian king Hammurabi, who oversaw expansive building projects and included construction laws in his famous Code of Hammurabi. The French began using it on roads in the first half of the 19<sup>th</sup> century, and the method made its way to America in the late 1800s.

Liquid asphalt—a bottom-of-the-barrel byproduct of crude oil refining—binds together rocks or sand (referred to as "aggregate"), providing roadbuilders with a quicker-drying and cheaper alternative to concrete. It's billed as a reusable material.

"The asphalt industry remains the country's most diligent recycler, with more than 99 percent of reclaimed asphalt pavement being put back to use," the National Asphalt Pavement Association states in the 2017 report on its annual recycled materials and warm-mix asphalt usage industry survey.

Yet the results of that same survey put the average percentage of reclaimed asphalt pavement in new asphalt mixtures nationwide at 20.1—meaning the overwhelming majority of the material that's laid down on roads is still newly refined liquid asphalt and mined aggregate. Meanwhile, there were more than 102 million tons of



reclaimed asphalt pavement stockpiled across the country at the end of 2017, according to the report.

“It’s not only the asphalt; we cannot continue to mine these aggregates from our mountains. It’s just not sustainable,” says Bahia. “Asphalt is very expensive, relatively speaking, so we can reuse it, and more importantly, these rocks are very good rocks. Recycle the good rocks—don’t throw them away. Recycling is becoming almost a necessity because we want to reduce cost.”

With that in mind, Bahia’s lab, the Modified Asphalt Research Center, recently began an 18-month project with the Recycled Materials Resource Center in the College of Engineering to performance-test asphalt mixes using 30- and 50-percent recycled content. By defining the properties that affect performance and establishing more effective testing methods, his group hopes to pave the way for wider adoption of asphalt containing higher levels of recycled content.

## Green and growing

One of Bahia’s former PhD students, Nima Roohi Sefidmazgi (MSCE ’11, PhDCE ’13), wants to go even further. He’s vice president of Green Asphalt, a New York-based company that’s one of the only in the country producing 100-percent recycled asphalt.

“On the scale we’re doing it in New York City, no other plant is doing it in the whole world,” Roohi Sefidmazgi says of the company’s Long Island City plant, which was featured in *The Wall Street Journal* in October 2018.

To produce a 100-percent recycled mix, Green Asphalt tweaked the typical process, heating the material indirectly, using a different type of filtering system for fumes from the heated asphalt, and treating the melted blend with a soy-based oil to recover its flexibility. The company tested an array of rejuvenating oils, including one derived from waste food oil that workers loved because it smelled like McDonald’s French fries.

The hardest part, though, was securing regulatory approval, which was Roohi Sefidmazgi’s main charge when he joined Green Asphalt in 2014. He worked with the New York City and New York departments



Green Asphalt paved Shore Road in Queens in New York City with its 100-percent recycled asphalt product. Photos courtesy of Green Asphalt.

of transportation to develop specifications for the production process and final product, backed by performance data from on-the-road testing.

New York City approved Green Asphalt’s mix for use in 2015, thus becoming the first major city in the country to green-light 100-percent recycled asphalt. In doing so, the city also found a convenient outlet for some of its milled asphalt.

Now, Green Asphalt hopes to make use of its hard-won technical and bureaucratic knowledge by partnering with companies around the world. Roohi Sefidmazgi says the company’s vision is that every road around the world will use 100-percent recycled asphalt by 2038.

The potential environmental and financial impacts are tantalizing. According to Roohi Sefidmazgi, using 1 million tons of 100-percent recycled asphalt instead of a 30-percent recycled product would result in a carbon footprint savings equivalent to roughly 16,000 houses’ worth of electricity per year. (The National Asphalt Pavement Association estimates the United States used 379.4 million tons of asphalt in 2017.)

And since Green Asphalt sells its mix for about 30-percent cheaper than an average 30-percent recycled mix, Roohi Sefidmazgi says, states could save millions of dollars.

“I think we’re very close to a tipping point,” he says.

## The path forward

Still, significant roadblocks remain for fully recycled asphalt. State departments of transportation aren’t eager to risk pavement performance without more proof; without agency interest, companies have little

motivation to spend money overhauling their production processes and testing new mixes.

“There’s kind of a constant negotiation between state agencies and contractors,” says Amir Ghalipour (MSCE ’11, PhDCE ’13), a project manager consultant with the Federal Highway Administration.

He says at this point the agency is promoting different sustainable practices, such as using recycled tires in asphalt and warm-mix asphalt, which is produced at lower temperatures. Ghalipour believes pavement with 100-percent recycled asphalt needs more performance evaluation. He says the Federal Highway Administration has focused on performance-driven specifications to ensure pavement longevity and to provide flexibility in materials selection.

Projects like Bahia’s could supply the data to help nudge state agencies toward approving mixes with higher levels of recycled content. He and his students are testing different rejuvenating oils, as well as methods of adding them to aged asphalt.

The end goal: Provide agencies and industry players with tests and standards that ensure recycled mixes perform as well as or better than conventional mixes.

As for acceptance? That will require movement on both sides, Bahia says. Agencies will need to adapt their thinking from controlling the components—something that’s harder to do for recycled mixes—to focusing on performance properties. Companies will need to buy equipment for new tests and train their workers.

“These machines cost more,” says Bahia. “But in the bigger picture, the costs of this equipment and the training are really very, very small compared to the cost of not recycling.”

# Food for Thought

## Five ways AI advances enrich your day

by Sam Million-Weaver

### Once the stuff of science fiction, conversations with computers are now almost commonplace.

Although we might not be asking to plot a course for alpha centauri, as Captain Kirk did in *Star Trek*, many of us have talked to a personal digital assistant like Apple's Siri or Amazon's Alexa to look up some obscure bit of trivia, secure a dinner reservation or set a reminder to pick up milk from the grocery store.

While these quotidian interactions might seem mundane, and our silicon assistants sometimes miss the mark, artificial intelligence has become an indispensable part of our modern lives.

The most sophisticated applications for artificial intelligence aren't obvious—in fact, they're so inconspicuous as to go unnoticed.

But, behind-the-scenes computers have become incredibly smart.

What's driving this robo-renaissance? Computer processing power has certainly improved over time, but perhaps more importantly, a subfield of artificial intelligence called machine learning has emerged and sent computer IQs skyrocketing.

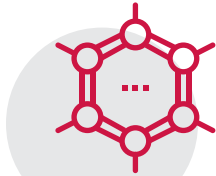
Artificial intelligence is a broad concept that encompasses all notions of machines being “smart”—in other words, they can connect and interact with you and other devices.

Machine learning algorithms are one approach to achieving artificial intelligence. Fundamentally, it's the idea that computers can teach themselves better than any human programmer can write instructions.

While there are a few different approaches to making a smart device, statistical approaches underlie modern machine learning. This approach enables computers to mimic the way that humans generalize from experiences to learn new things.

That said, machine learning hinges on training computers with correct examples—for example, teaching a computer to identify a puppy might require a researcher to feed several thousand “puppy” labeled images into a computer program called a neural network, which would then learn to identify distinguishing features of a dog on its own.

Machine learning excels at much more than picking out pictures of puppies. In fact, these powerful algorithms are helping to advance research in many areas in addition to the roles they play in improving our daily lives. You can read how College of Engineering researchers are applying artificial intelligence and machine learning algorithms on the following pages. In the meantime, here are five ways you may not realize artificial intelligence affects your world.



## Healthcare

1

Machine learning is a powerful tool for pattern recognition, making it a natural fit for helping doctors identify warning signs for disease. For example, artificial intelligence can spot malignant cells in images of biopsy samples as accurately as human technicians. And we're now able to measure genetic changes and untold thousands of markers in the blood, offering the possibility that machine learning could tease out some combination of indicators that correlate with risks for cancer, heart attack or stroke in otherwise healthy patients from a simple blood test. That's one goal of the National Institute of Health-funded Center for Predictive Computational Phenotyping, a partnership among UW-Madison, the Morgridge Institute for Research and the Marshfield Clinic Research Foundation.



## Security

2

It's one of your worst nightmares: A stolen credit card number leaves you on the hook for thousands of dollars in unauthorized transactions. Cyber crime currently costs the world approximately \$600 billion annually, according to estimates from security technology company McAfee. But increasingly, you can avert financial catastrophes thanks to machine learning. Sophisticated algorithms can familiarize themselves with your normal spending patterns, and immediately flag transactions that seem suspicious.



## Transportation

3

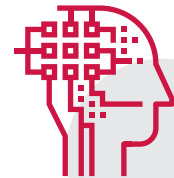
Self-driving cars are creeping ever closer to reality, and autonomous automobiles do indeed make use of machine learning algorithms for navigation. Even now, however, we benefit from machine learning in our daily commutes. Popular navigation tools like Google Maps and Waze analyze traffic data to suggest optimum routes, while ride-hailing apps like Uber use machine learning algorithms to match drivers with passengers and predict ETAs. Sick of congested roads? Pittsburgh installed smart stoplights in 2016 and slashed time waiting in traffic by roughly a quarter. Your city might be next.



## Entertainment

4

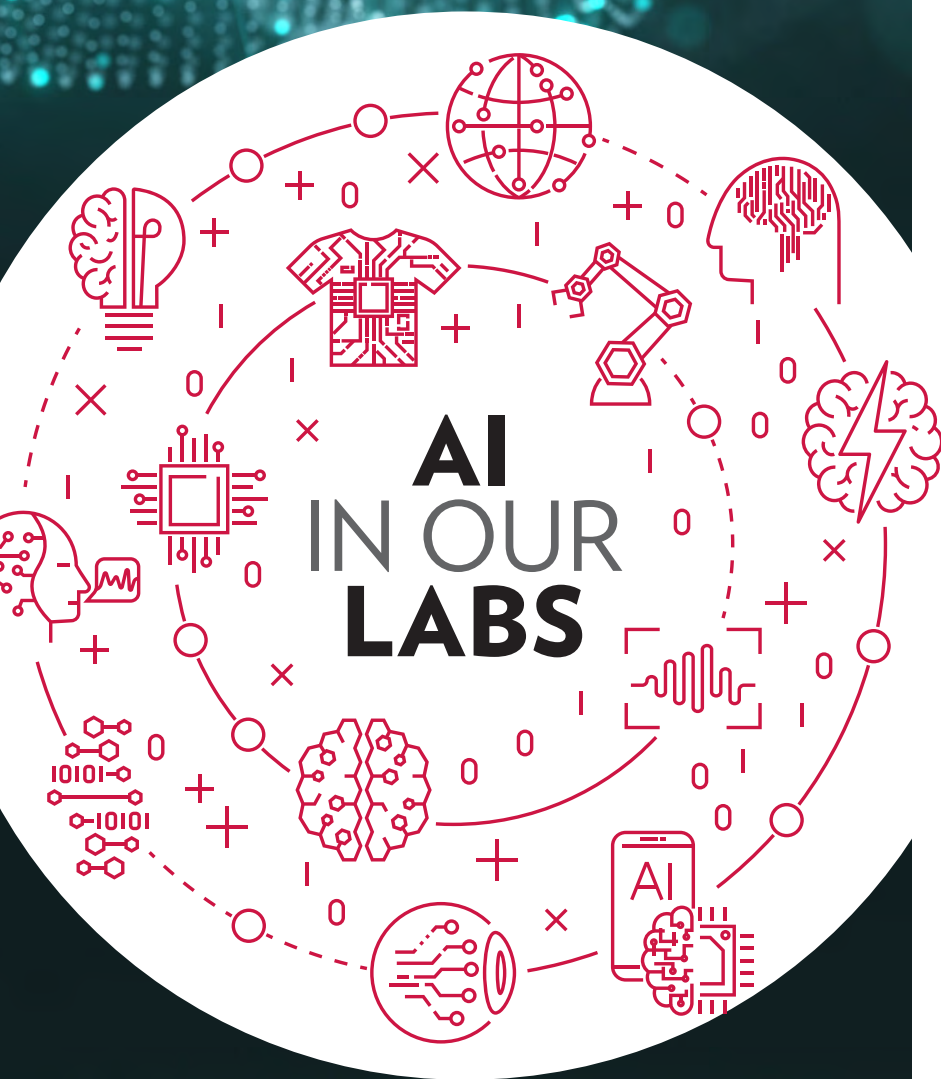
No longer just a plot device, artificial intelligence now plays a starring role in helping create movie magic. Machine learning already helps suggest a new favorite movie or TV show based on what you've watched before, thanks to the uncannily accurate recommendation algorithms on popular content streaming platforms like Netflix, Hulu or Amazon Prime. But the technology is also poised to create jaw-dropping visual effects: Algorithms can quickly and automatically take care of a painstaking process called rotoscoping that separates footage of people or objects from their backgrounds.



## Connection

5

Translation is another sector where machine learning shines. Algorithms can teach themselves the nuances of a language from the vast corpus of human-translated texts that already exist online. Once trained, digital translators can facilitate conversations in real time. If you're in a foreign country looking for love, dating apps like Tinder rely on machine learning to suggest promising connections based on the profiles you've previously swiped through. And once you're on that first date, order the perfect beverage using beermapper, a machine learning-based app developed by Robert Nowak, the Nosbusch Professor in electrical and computer engineering, that analyzes your unique taste preferences to recommend delicious brews.



*Although still in its relative infancy, artificial intelligence is rapidly gaining a lasting place in popular culture. Yet, as much as we might appreciate online shopping recommendations based on our browsing history or our phone's ability to unlock at a mere glance, AI perhaps is even more important in advances in many areas of research.*

*Read on to learn about a few of the ways College of Engineering faculty, staff and students are using AI and machine learning to speed discovery and unlock knowledge in myriad fields.*

## WHAT'S THAT YOU SAY?

### Using audio to accurately identify a genetic risk

Biomedical engineering PhD student Arezoo Movaghar is leveraging her training in computer science and artificial intelligence to better understand neurodevelopmental disorders such as autism spectrum disorder and fragile X syndrome.

In particular, she's looking at the underdiagnosed fragile X premutation, a genetic condition affecting millions of people globally. People who carry the fragile X premutation have higher risk for neurodegenerative disorders, infertility, and having a child with disability.

While costly and time-consuming, genetic testing for the premutation can help people with it better understand why they experience certain symptoms and build a more informed health plan.

Movaghar and her colleagues developed an easier, more cost-effective way to identify carriers based on the knowledge that people with the premutation exhibit certain language patterns. "By using machine learning we were able to develop a method to identify premutation carriers—based on just five minutes of speech—with high accuracy," says Movaghar, noting that a genetic test is still required to confirm the premutation.

Now, her work integrating machine learning into identification of the fragile X premutation may lead to a user-friendly mobile app.

**More:** [www.engr.wisc.edu/using-artificial-intelligence-big-impact-neurodevelopmental-research/](http://www.engr.wisc.edu/using-artificial-intelligence-big-impact-neurodevelopmental-research/)





## A FRESH PERSPECTIVE ON CONTAMINATED AIR

As we move through our daily lives, we're exposed to any number of vapors, dusts, fumes or gases—many of which we likely aren't aware of. Yet, for the sake of our health and safety, there's a growing need to monitor and understand the chemicals in our environment.

"We want people to have more information about what they're exposed to in their daily lives, especially within cities," says Victor Zavala, the Baldovin-DaPra Associate Professor in chemical and biological engineering.

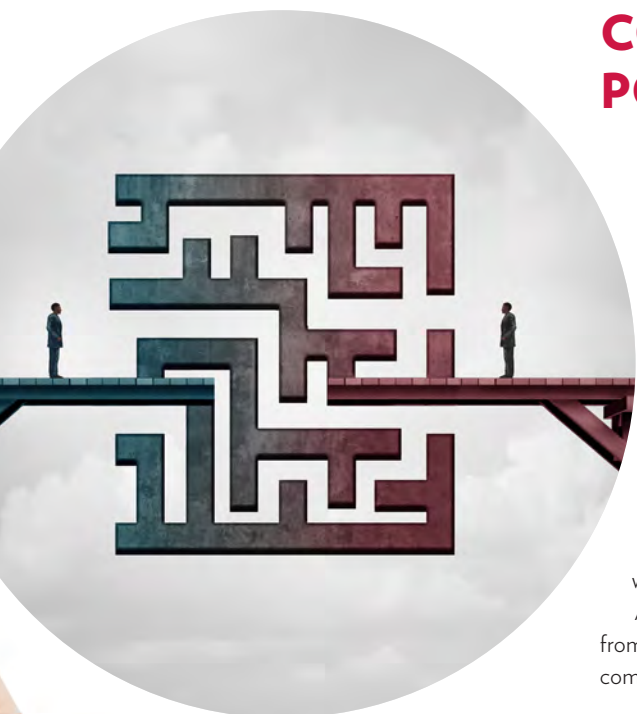
He and his colleagues are developing liquid crystal sensors that can quickly detect trace amounts of air contaminants—everything from carbon monoxide to chemical weapons such as sarin.

One sensor can detect specific sarin concentrations within a few seconds. To accelerate that response time, they turned to artificial intelligence algorithms, which could spot changes in patterns inside the liquid crystals after only three seconds—correctly identifying exposure to the sarin-like chemical with 99-percent accuracy.

Now, the team is verifying that accuracy by running molecular simulations and computationally modeled interactions between contaminants and the liquid crystal—linking the abstract AI "thoughts" to actual physical mechanisms occurring within the liquid crystal sensors.

**More:** [www.engr.wisc.edu/leveraging-ai-monitor-exposure-air-contaminants/](http://www.engr.wisc.edu/leveraging-ai-monitor-exposure-air-contaminants/)

Small, portable liquid-crystal-based sensors could help detect people's exposures to airborne contaminants in a matter of seconds. Photo: Renee Meiller.



## COMPUTING CAN CUT THROUGH POLITICAL CHATTER

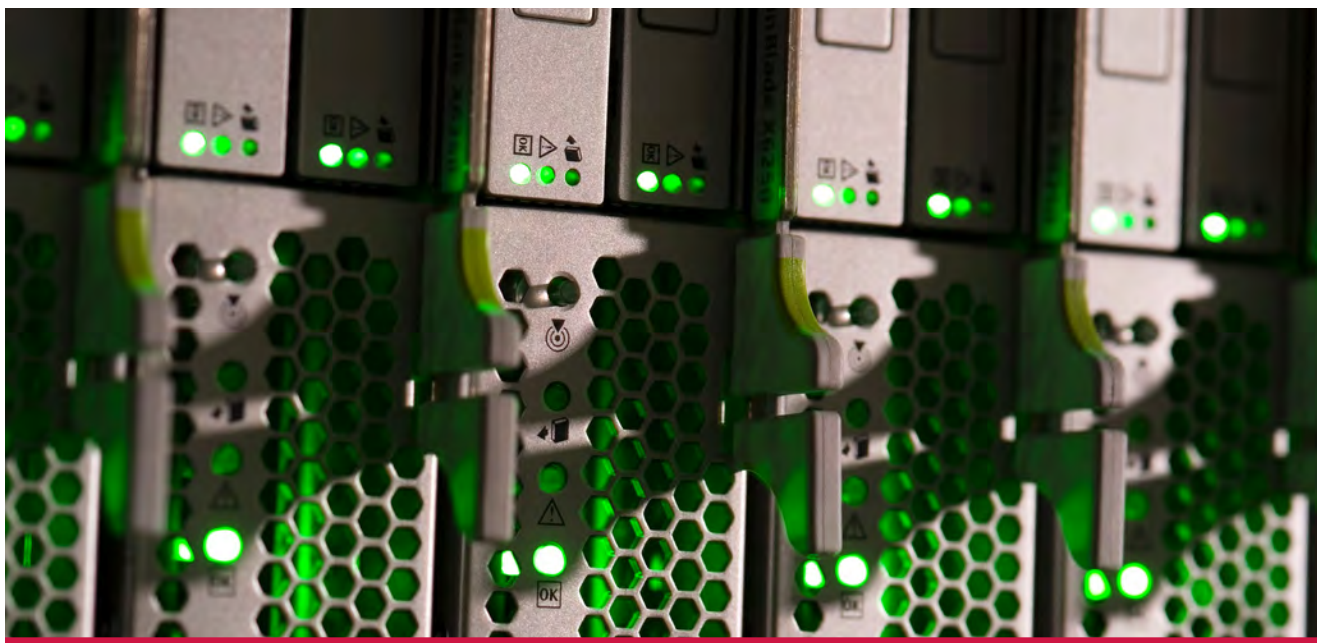
Electrical and Computer Engineering Professor William Sethares and Journalism Professor Lewis Friedland have undertaken one of the most ambitious efforts ever to understand how people in an entire state talk about politics, and how those conversations have changed over time.

Drawing on social media posts, public opinion polling, news coverage and in-person interviews from across Wisconsin stretching back to 2010, they aim to paint a picture of political interactions as a living, changing environment—a "communication ecology"—with webs of interaction between people and institutions in the state.

In an effort to develop a comprehensive picture of how people communicate about politics, and how those conversations can be shaped by media, social networks and personal interactions, they're harnessing the power of machine learning to detect how people of opposite political persuasions assign different meanings to the same words—for example, words such as "regulation" or "government."

And even though untangling partisan gridlock will require substantial empathy and effort from people across the political spectrum, the researchers note that understanding the communication environment is an important first step toward bridging the divide.

**More:** [www.engr.wisc.edu/computers-help-close-partisan-divides/](http://www.engr.wisc.edu/computers-help-close-partisan-divides/)



The new Machines, Algorithms and Data Lab (MADLab) at UW-Madison aims to make machine learning more effective and broadly applicable. *Photo: Jeff Miller.*

## SELF-DEFENSE: MODERNIZING MACHINE LEARNING FOR A SAFER SOCIETY

Artificial intelligence has become so smart and commonplace that most people accept computer-generated restaurant recommendations or movie suggestions without blinking an eye.

However, current machine learning capabilities aren't optimized for handling highly complex, rapidly changing, or uncertain environments— aspects the U.S. Air Force Office of Scientific Research and the Air Force Research Laboratory believe are critical to our national defense. That's why those organizations have awarded

\$5 million in funding to a center of excellence led by Nosbusch Professor of Electrical and Computer Engineering Robert Nowak. Called the Machines, Algorithms and Data Lab, or MADLab, it will help build the next generation of machine-learning methods needed to keep our country safe.

The new center is an important addition to an already thriving community of data science, machine learning and artificial intelligence research on the campus.

"MADLab harnesses the collective talent of world-renowned researchers who already have made significant contributions to machine learning," says Nowak, who also leads the machines, algorithms and data research effort in the Grainger Institute for Engineering and is a fellow of the Wisconsin Institute for Discovery at the university. "Data science and machine learning research is thriving at UW-Madison. MADLab and the National Science Foundation-funded Institute for Foundations of Data Science in the Wisconsin Institute for Discovery are working together to develop the science and technology of tomorrow."

**More:** [www.engr.wisc.edu/making-machine-learning-robust/](http://www.engr.wisc.edu/making-machine-learning-robust/)



## ELEVATING EFFICIENCY FROM FACTORY FLOOR TO WAITING ROOM

Whether he's examining a production system for an automaker or the workflow in a hospital pharmacy, Industrial and Systems Engineering Professor Jingshan Li develops models to improve efficiency, throughput and quality.

And while he comes from a manufacturing background, he has gradually expanded into healthcare research. Over the course of his career, he has collaborated with the likes of Toyota, Chrysler, General Motors, Kraft Foods, UW Health and Dean Health System. Currently, he is working with Madison's St. Mary's Hospital to develop a prediction model for patient readmission.

By using machine learning techniques, Li and his group can predict the risk of readmission after discharge and identify critical factors, allowing doctors to personalize treatment.

"There are a lot of opportunities," he says. "I think we can help to improve our healthcare systems. It's really critical. It impacts everyone's life."

**More:** [www.engr.wisc.edu/factory-floor-waiting-room-li-elevates-efficiency/](http://www.engr.wisc.edu/factory-floor-waiting-room-li-elevates-efficiency/)

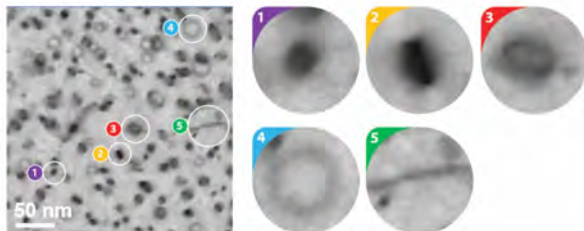


## BEYOND 20/10: EAGLE-EYED ALGORITHM ACES IMAGE ID

When artificial intelligence pairs up with machine vision, computers can accomplish seemingly incredible tasks—think, for example, of Facebook's uncanny ability to pick out people's faces in photos.

Beyond its utility as a helpful social media tool, advanced image processing someday could help doctors quickly identify cancerous cells in images from biopsy samples or enable scientists to evaluate how well certain materials withstand conditions in a nuclear power reactor.

"Machine learning has great potential to transform the current human-involved approach of image analysis in microscopy," says alum Wei Li (MSMS&E '18).



An image of radiation-damaged materials resembles a cratered lunar surface. Machine learning can help with nuclear reactor design by quickly finding and identifying specific varieties of defects. *Image: Kevin Fields.*



As a student, Li and his collaborators used machine learning to rapidly sift through electron microscopy images of materials that had been exposed to radiation and to identify a specific type of damage—a challenging task because the photographs can resemble a cratered lunar surface or a splatter-painted canvas.

The result? After a bit of training, the computer worked more quickly and accurately than its human counterpart.

"Human detection and identification is error-prone, inconsistent and inefficient. Perhaps most importantly, it's not scalable," says Harvey D. Spangler Professor of Materials Science and Engineering Dane Morgan. "Newer imaging technologies are outstripping human capabilities to analyze the data we can produce."

**More:** [www.engr.wisc.edu/eagle-eyed-algorithm-outdoes-human-experts/](http://www.engr.wisc.edu/eagle-eyed-algorithm-outdoes-human-experts/)

# 5 QUESTIONS WITH DAN THOMA ABOUT 3D PRINTING



Since 2015, Dan Thoma has been the director of the Grainger Institute for Engineering and a professor of materials science and engineering. Thoma is also an alumnus of the College of Engineering, having received his PhD in metallurgical engineering in 1992.

Prior to his return to UW-Madison, Thoma was a deputy division leader for the Los Alamos National Laboratory Materials Science and Technology Division, where he steered the creation of the laboratory's alloy design and development team and headed its Materials Design Institute.

Thoma's expertise in metal additive manufacturing, alloy development, digital manufacturing, advanced materials and related areas is an asset to the Grainger Institute for Engineering, which includes a focus on advanced manufacturing and accelerated materials discovery.

Additive manufacturing, sometimes referred to as 3D printing, has in recent years drawn the interest of manufacturers around the world because of its unique capabilities. We asked Dan Thoma, who studies additive manufacturing in his lab on campus, a few questions about the current capabilities of 3D printing and where it might lead manufacturers in the future.



**1** *How are 3D printers currently being used in industry?*

3D printers are being used at many levels in the manufacturing process, including prototyping for design purposes, tooling, and component fabrication.



**2** *What products are most practical to 3D print?*

There are many arguments that low-volume, high-cost parts are best for additive manufacturing. Components with complex functionality that cannot be achieved through conventional processing routes are most attractive. However, higher-volume components with distinct functionality are also being used—for example, GE Aviation's components for fuel dispersal in jet engines.

**3** *For manufacturers hoping to incorporate 3D printing or additive manufacturing into their processes, what are the greatest challenges?*

Each individual industry can best answer that question, but the cost analysis, which is industry-specific, is the most important factor when deciding whether or not to incorporate additive manufacturing. The business decision about what can be done versus what should be done is a function of the supply chain, operating costs and productivity efficiency. These numbers remain difficult to fully determine as the field matures. Many companies have different levels of risk that they are willing to adopt in implementing new technologies. That said, increased functionality in components can offer significant advantages for some industries.

**4** *What is the primary focus of research in the 3D printing field right now?*

This may be a biased perspective, but I would argue that certification and qualification is the biggest area of research in the field of 3D printing. How do you ensure components will function properly over their lifetime? The design, feedstock, properties and materials selection are all topics that fit into the overarching area of certification and qualification. For more basic studies, however, design of new functionality is where really fundamental efforts are using 3D printing as a tool.

**5** *What is the future potential for 3D printing in manufacturing?*

Exciting areas in manufacturing with 3D printing potential include *in situ* qualification and quality control, higher fabrication rates, thermal management, multi-materials, metamaterials, biomanufacturing and new fabrication sources. In January 2019, the Grainger Institute for Engineering sponsored the first in a series of additive manufacturing workshops to explore new research opportunities across campus as well as engage industrial perspectives.



# ENERGIZING IMPACT

In the tiny unincorporated burg of Juda, Wisconsin—population 357, per the 2010 U.S. census—there’s a clear community centerpiece.

“If you want to know what the trick-or-treating hours are, you call the school,” says Scott Anderson, a high school math and engineering teacher at Juda School, a building that houses roughly 300 students from 4K to grade 12.

So any project touching the school is apt to attract interest in this community that sits 6 miles north of the Wisconsin-Illinois border—an enthusiasm that became apparent to a group of our engineering students during the fall 2018 semester.

As part of UW-Madison’s UniverCity Year partnership with Green County, a team from the Department of Civil and

Environmental Engineering’s senior capstone design course is proposing a renewable energy system to help offset Juda School’s energy expenses by 25 percent.

Each semester, civil and environmental engineering students, along with some from the department’s geological engineering major, tackle projects for clients that range from private companies to state agencies and other public entities. Adjunct faculty members and team mentors who are also practicing engineers lend advice on tactical elements like putting together proposals, delivering presentations, project management and estimating costs. Then it’s up to the students to deliver a detailed solution—giving them a taste of the kind of work they’ll face after graduation.

To put together their final design, Morgan Keck and fellow seniors Connor Acker, Emma Connell, Brooke Marten and Robin Ritchey analyzed possible renewable energy systems for Juda School from five perspectives: environmental impact, safety, constructability, financial cost and social considerations.

They’ve looked at systems used at schools across the state, as well as one in Laramie, Wyoming, and consulted with topic experts like their team mentor Casey Joyce, a project manager at solar energy contractor SunPeak, and James Tinjum,



UW-Madison engineering students (far right, clockwise) Brooke Marten, Robin Ritchey, Emma Connell, Morgan Keck and Connor Acker pose with team mentor Casey Joyce (middle), Juda High School teacher Scott Anderson (front) and his students outside of Juda School in September. *Photo courtesy of Scott Anderson.*

an associate professor in CEE and the Department of Engineering Professional Development, who has extensive experience with wind turbines.

All that research and analysis pointed to a system that incorporates both a geothermal heating and cooling system and a rooftop solar panel array to bolster Juda School’s existing solar setup. The students are also exploring funding options that would help the school district pay for such a major upgrade.

“It’s given me confidence that I could go work on something that I’ve never really





An aerial view of Juda School in rural Green County. The building houses all of the district's students from 4K through high school. *Photo courtesy of Juda School District.*

experienced before and be able to learn it quickly," says Ritchey.

Visits to Juda have also allowed the UW-Madison engineers to connect with the nine students in Anderson's Intro to Engineering class. Anderson says the project has not only shown his students what engineers do on the job, but it's allowed them to see a viable path from a high school of less than 100 students to a university with more than 40,000.

"It shows them the opportunities that are out there in the world," he says. "It's a great motivator for my students."

Of course, senior capstone design projects come with the caveat that they're conceptual in nature; a professional engineering firm would need to review the work and develop the detailed final design. But Anderson says he's hopeful that within a few years, the school will start to install a system.

"It's going to be ready to go. It's been engineered, it's been thought out, all the research is done," he says. "And then when an opportunity appears, we're going to be poised to jump on it."



Photos: Sam Million-Meaver

## AUTOMATIC, AND ANYTHING BUT ORDINARY

Thanks to a partnership with industrial automation giant Rockwell Automation, our engineering students can get their hands on today's most advanced industrial manufacturing technologies.

That's one reason the Rockwell Automation Industrial Connected Enterprise Laboratory is such a valuable resource. "Rockwell has a mission to expand human potential," says Rockwell Automation CEO Blake Moret, whose company has a long history of supporting initiatives in the college in both research and education. "Automating mundane tasks allows human workers to focus on challenging problems that need critical thinking."

The new lab, which opened in October 2018, will support four courses on topics ranging from process control to data techniques to cybersecurity, with more classes slated for the future. And plans are already in place to add new flexible automation systems and an industrial data center.

"We are doing things that aren't traditionally done," says Dan Thoma, director of the Grainger Institute for Engineering, which oversees the lab. "And it's helping our students build up a comfort zone and familiarity with state-of-the-art technology from Rockwell."

**More:** [www.engr.wisc.edu/automatic-anything-ordinary-partnership-rockwell-prepares-engineers-excel/](http://www.engr.wisc.edu/automatic-anything-ordinary-partnership-rockwell-prepares-engineers-excel/)



## NUCLEAR KATIE

Sparkling online reactions with lots of energy



In an age increasingly defined and connected by online discourse, Katie Mummah is taking full advantage of the digital tools at her disposal—all in the name of science.

Mummah, an engineering physics PhD student, is known as “Nuclear Katie” (@nuclearkatie) on Twitter, where she’s leveraged her passion for nuclear science into a social media presence that is at once brimming with enthusiasm for science and nuclear energy and teeming with factual information.

Mummah’s goal? To inject the online debate surrounding nuclear technology with some fact-based optimism. Her approach? Frequent info-laden posts supplemented by a healthy dose of the internet’s lingua franca: memes, GIFs and retweets. Her online charisma has to-date netted Mummah more than 3,000 followers on Twitter. And while she enjoys engaging in the social media banter, what Mummah really wants is to open minds.

“As a nuclear scientist, I see myself as an advocate for nuclear energy,” Mummah explains.

She says her approach to social media is all about balance. “There are nuclear scientists who only present facts and are very dry,” she says. “Then there are really emotional people. I try to sit in between, where I’m sharing my enthusiasm for nuclear energy with facts, and in a way that I think is interesting and provides a lot of context. I like to answer questions and to be respectful when I’m making a point.”

A key ingredient in Mummah’s social media success is the sheer profusion of her enthusiasm for nuclear science in the form of nonstop activity. Her prolificacy is a constant whether she’s preparing for qualifying exams or working on her research, in which she models the nuclear fuel cycle from mine to repository. Mummah hopes the computer models she’s developing will make it more efficient for the International Atomic Energy Agency (IAEA) to keep track of nuclear materials in the future.

The federal government’s national laboratory system also sees promise in Mummah’s efforts. In 2018, she spent her second summer conducting research at Los Alamos National Laboratory in New Mexico, where she was funded by a Glenn T. Seaborg Institute summer fellowship to continue developing her models. The fellowship was funded through the Los Alamos and Lawrence Livermore National Labs as a part of the National Security Education Center.

“Basically, I wanted to see if the models I’ve been working on at Wisconsin could be integrated with tools that’ll go to the IAEA,” she says. “I wanted to know: Can these models be of benefit? Is this something that’ll be useful. The verdict is ‘yes.’”

**More:** [www.engr.wisc.edu/lively-social-media-presence-grad-student-shares-enthusiasm-nuclear-energy/](http://www.engr.wisc.edu/lively-social-media-presence-grad-student-shares-enthusiasm-nuclear-energy/)



# WORTH A THOUSAND WORDS

## Visualization course teaches students to view data in graphic detail

Show most people a spreadsheet full of numbers and their eyes are apt to glaze over. Turn that data into a graphic, though, and suddenly it makes sense.

Just ask the student in Professor John Lee's data visualization class who had previously muddled through a course on health policy—only to have a classmate's visual representation of healthcare investments and outcomes around the world belatedly deliver some key lessons.

"I finally understand what they taught us last semester!" she blurted out.

In *Interactive Data Visualization*, a special topics course offered through the Department of Industrial and Systems Engineering, a mixture of undergraduate and graduate students learn to combine, organize and present data. They learn the ins and outs of the statistical programming language R and its open-source software RStudio, how to plot data in the visualization package ggplot2, and how to create interactive web applications in R Shiny.

Each student chooses a topic that's both personally interesting and meaningful to society, gathers and manipulates datasets, and builds out a visualization.

First-year graduate student Ankur Aggarwal drew on his decade of work experience in the energy sector to develop graphics that detail the energy sources of American power plants.

"I hope to create awareness about optimal consumption of energy in U.S. households, cutting back on usage of fossil fuels and focusing on renewable energy sources," says Aggarwal, who's studying manufacturing and production systems. "Also, I intend to highlight the growth of power plants running on various renewable energy sources like solar, wind, biomass and geothermal."

Katie Mummah, a PhD student in the Department of Engineering Physics, also examined the energy landscape. Her visualization allowed users to see the sources of their electricity, both on a state and national level.

"I don't think most people know the largest energy source in their state; for Wisconsin, it is overwhelmingly coal. I also want people to see the way their energy has changed over the last few decades," she says, noting how wind power has grown exponentially over the past two decades to account for more than 6 percent of U.S. electricity in 2017.

Other students have taken on complex issues such as the prevalence of cancer across the state of Wisconsin as a function of arsenic levels in groundwater.

While Lee has taught the course three times in the past five years, in 2018 he added a twist by borrowing a format for feedback from a friend teaching a creative writing course at the University of Iowa. The workshop method provides students—working in small groups—with a framework for thoughtfully delivering constructive critiques and asking for feedback to ultimately improve their projects.

"It can be challenging to present constructive feedback," says Lee, who is the Emerson Electric Quality & Productivity Professor in industrial and systems engineering. "There's a temptation to say, 'Oh, it's ugly. It doesn't work. It's wrong.' You have to learn how to present



Students in Professor John Lee's data visualization course gather and manipulate data and build interactive visualizations on meaningful topics, such as energy sources across the United States and the links between cancer and arsenic in groundwater. *Photo: Tom Ziemer.*

the feedback, but then you also have to learn to accept the feedback. It's hard."

So is presenting a visualization, which is why Lee invited Meriko Borogove, a former senior director of engineering at Apple who led development on the iPhone, to speak to the class. She shared firsthand lessons from presenting to Apple executives, like figuring out their individual quirks and preferences.

"Know your audience. Know what they like," she told the students.

When Borogove offered to stay after class to critique the students' in-progress visualizations, Mummah seized the opportunity to get feedback from a seasoned professional.

"Data and numbers are such a fundamental part of engineering," says Mummah. "This class has given me the tools to visualize data faster, easier and better than I ever have before. I'm learning to think from a design standpoint to think critically about how I present data."

## 'RHODES' SCHOLAR ADDS MILES TO HIS EDUCATION

Noah Rhodes didn't spend much time in Wisconsin during 2018.

The electrical and computer engineering senior spent most of January 2018, in Guatemala, working on a service project for Engineers Without Borders. Then, merely four days after returning from a summer study abroad program in Copenhagen, Rhodes packed up his car and drove to Golden, Colorado, for a 16-week-long research internship at the Department of Energy National Renewable Energy Laboratory, or NREL, a state-of-the-art facility tucked into the foothills of the Rocky Mountains.

For Rhodes, the inconvenience of moving—twice—was well worth the opportunity to pursue a research project at NREL, where he worked in the building and energy efficiency subgroup.

Rhodes is no stranger to undergraduate research—he interned in the Wisconsin Electric Machines and Power Electronics Consortium for a summer and spent a semester using image-processing algorithms to interpret biological images for a faculty member.

At NREL, however, Rhodes had an unprecedented chance to take the lead on his own project, working on strategies to help buildings blend their energy sources from self-generated renewables and the conventional power grid.

Finding the balance between self-contained microgrids and the existing energy infrastructure requires a deep understanding of theoretical optimization models and real-world hardware. It's a challenging problem, which is part of the appeal.

"I enjoy working on renewable energy because the power grid is a massively complex network," says Rhodes. "You need to understand both the whole system and the tiny details."

After completing his coursework requirements in fall 2019, Rhodes plans to apply to graduate school, where he hopes to continue working on power systems and renewable energy. "Doing independent research has been so valuable," says Rhodes. "The experience really helped me be confident in my decision to apply to grad school next year."



*"I enjoy working on renewable energy because the power grid is a massively complex network. You need to understand both the whole system and the tiny details."*



### Materials informatics fellowship trains cutting-edge next-generation workforce

Materials science is at the beginning of major transformation driven by the integration of data science and machine learning technologies. This integration is creating the new field of materials informatics, which applies computational and machine learning tools to characterizing and discovering materials. To efficiently realize the full potential of materials informatics, it is essential to educate today's students in this novel and interdisciplinary area. That's just one reason why a newly expanded summer fellowship in materials informatics presents an exciting opportunity for our engineering undergrads.

The Citrine NextGen fellowship, with additional support from the National Science Foundation, the UW-Madison Materials Research Science and Engineering Center, and the UW-Madison Graduate School supported nine students (six from UW-Madison, two from the University of Puerto Rico at Mayagüez, and one from Hope College) in summer 2018 as they worked to develop critical skills in materials informatics on our campus and in Silicon Valley.

**More:** [www.engr.wisc.edu/materials-informatics-fellowship-trains-cutting-edge-next-generation-workforce/](http://www.engr.wisc.edu/materials-informatics-fellowship-trains-cutting-edge-next-generation-workforce/)

## WITH CREATIVITY AND CAREFUL ENGINEERING, UNDERGRADS AWE HYPERLOOP JUDGES

Engineers, investors and innovators from around the globe gathered in the Southern California desert in July 2018 to test their prototypes for an ultrafast subterranean transportation concept at the 2018 SpaceX Hyperloop Pod Competition.

The private space exploration company SpaceX founded the annual hyperloop pod contest in 2015. In 2018, competition was fierce, with the best 18 teams from around the world vying for the win. The rules were simple: fastest pod took top prize.

After a grueling week of technical testing to ensure the competing vehicles could withstand hurtling through an airless tube at nearly one-third the speed of sound, four teams were selected to give presentations on the final day of competition about their team's design.

Although it did not take the competition's top prize, our Badgerloop team was one of those four—chosen because its initial presentation on the first day of competition impressed the judges. Badgerloop also established itself among the top competitors during the previous two contests, taking home back-to-back innovation awards.

Unlike many of its competitors' teams, which are populated largely by graduate students who work full-time on their designs and receive major (or full) funding from their institutions or corporate partners, the Badgerloop team is made up almost entirely of undergraduate students from departments across campus who devote hours of their spare time to the team and must fund-raise for materials and resources on their own.



The Badgerloop team at the 2018 SpaceX Hyperloop Pod Competition in California.

**More:** [www.engr.wisc.edu/strong-showing-badgerloop-spacex-hyperloop-pod-competition/](http://www.engr.wisc.edu/strong-showing-badgerloop-spacex-hyperloop-pod-competition/)

## A FRESH APPROACH TO ROCKET SCIENCE

Wisconsin's state motto may be "Forward," but a team of our engineering students is looking upward at the stars.

The students aim to design, build and launch a rocket capable of reaching an altitude of 100 kilometers—the so-called Kármán line that marks the threshold of where Earth's atmosphere ends and outer space begins. In order to achieve such great heights, they plan to build a liquid-propelled rocket more than 20 feet long and weighing more than 1,000 pounds.

If they are the first team to achieve this lofty goal by Dec. 30, 2021, the students stand to win a \$1 million prize in a first-of-its-kind contest called The Base 11 Space Challenge, sponsored by the companies Base 11, Dassault Systems and Spaceport America.

"I'm passionate about a future where we are exploring the cosmos," says Brandon Wilson, a senior majoring in engineering mechanics and astronautics who is the team's co-founder and technical lead. "In the long term, I hope to work toward exploring other stars."

That passion motivates all 21 of the students currently on the UW-Madison team, who will also gain one-of-a-kind real-world experience constructing a rocket. They're aiming to test-fire their first small-scale prototype in spring 2019.

**More:** [www.engr.wisc.edu/lift-off-wisconsin-student-team-shoots-stars-rocket-contest/](http://www.engr.wisc.edu/lift-off-wisconsin-student-team-shoots-stars-rocket-contest/)



## THE ART OF MAKING OVER A MUCH-LOVED MASCOT

Buckingham U. Badger, or Bucky, for short, is the beloved mascot of the University of Wisconsin-Madison, and he has worn essentially the same cardinal red and white striped sweater since 1940.

But during summer 2018, Bucky finally tried on some new outfits, thanks to a public art and fund-raising event called Bucky on Parade. Madison witnessed an invasion of 85 six-foot-tall fiberglass likenesses of UW-Madison's favorite burrowing mammal—each one decked out in Technicolor splendor by local artists.

One of those artists was Aislen Kelly, a chemical and biological engineering undergraduate who began her UW-Madison college education in fall 2017. She found out about the Bucky on Parade project through social media and submitted her design proposal shortly after arriving on campus as a freshman.

Inspired by the community aspects Madisonians hold near and dear, Kelly painted the “Madison Traditions” Bucky, which stood proudly at the intersections of State and Frances streets downtown.

She adorned Bucky's red-striped sweater with images of local legends and landmarks—the State Street sign on his right shoulder, the Capitol dome on his torso, a pink flamingo on his left forearm, and an iconic yellow Memorial Union sunburst emblazoned on his back. A modified version of the famous Las Vegas sign proclaims “Welcome to Fabulous Madison Wisconsin” across Bucky's chest.

“It's been really rewarding seeing it, seeing how other people perceive it,” says Kelly.

At the end of the summer, a number of the statues were auctioned off at a gala finale party, with the proceeds benefitting the nonprofit organization Garding Against Cancer, the Madison Area Sports Commission, and other community charities.

“That's what the project was meant to do: bind the community together for a common cause,” she says.

**More:** [www.engr.wisc.edu/brushes-behind-madison-traditions-bucky/](http://www.engr.wisc.edu/brushes-behind-madison-traditions-bucky/)

Sophomore Aislen Kelley poses with the “Madison Traditions Bucky” statue that she painted. Photo: Sam Million-Weaver.





Women in Kenya's Tharaka Nithi County try out the water vest designed by first-year students in the College of Engineering. Photos: Lesley Sager.

## A SIMPLE, SUSTAINABLE SOLUTION FOR A PHYSICALLY TAXING TRANSPORT

When she enrolled in *Interdisciplinary Engineering 170*, biomedical engineering student Nicole Froelich knew the intro-to-design course would enable her and her classmates to work with a client on a tangible project.

Little did she know, however, that her project would lead her more than 8,000 miles from campus.

Yet in late-May 2018, Froelich and four teammates found themselves in Kenya, hand-delivering their product: a double-sided vest that will allow women in rural locales to carry water and other goods long distances in a less physically taxing way.

Transporting water was time-consuming and physically taxing: Carrying a 20-liter plastic jerrycan on their backs, with a rope they grip with their hands and wrap around their foreheads, was causing the women headaches and neck and spine problems.

The student design team considered a few ideas. Ultimately, using a canvas sail donated by the Hooper Sailing Club at UW-Madison, the students created a double-sided vest that matches the capacity of a standard jerrycan while allowing for hands-free, unhindered movement.

In spring 2018, five team members—Froelich, Jacob Cohn (biomedical engineering), Isabel Reams (civil and environmental engineering), Molly Snow (environmental engineering) and Henry West (industrial engineering)—traveled to Kenya to teach residents there to make the vests using woven-nylon rice bags, ensuring the process is sustainable at the local level and giving them full control over the product.

Not only were the women excited when they saw the vests, but within minutes, they had imagined uses for them beyond water, such as transporting produce to the market, holding materials for weaving baskets, and even carrying children.

**Video and story:** [www.engr.wisc.edu/vest-best-students-design-water-carrying-device-rural-kenyans/](http://www.engr.wisc.edu/vest-best-students-design-water-carrying-device-rural-kenyans/)

## NAE POSTHUMOUSLY HONORS SENSING AND CONTROLS PIONEER BOB LORENZ

On Feb. 7, 2019, the National Academy of Engineering (NAE) posthumously named Robert Lorenz, who was a longtime University of Wisconsin-Madison mechanical engineering professor, to its 2019 class of fellows.

The academy recognized Lorenz's contributions to modeling and control of cross-coupled electromechanical systems for high-performance electric machines and drives. He is among 86 new members and 18 foreign members elected to the NAE in 2019. The designation is among the highest professional distinctions accorded to an engineer, and membership honors those who have made outstanding contributions to engineering research, practice or education.

Lorenz passed away on Jan. 27, 2019, after a battle with cancer.

After joining the UW-Madison engineering faculty in 1984, he immediately got involved with the then-new Wisconsin Electric Machines and Power Electronics Consortium (WEMPEC), an academic-industry partnership he helped to grow into one of the largest and best-known university consortia in its field today, with more than 85 company sponsors. The UW-Madison consortium, which includes more than 80 faculty, staff, undergraduate and graduate students, and international scholars, supports innovative research to benefit its company sponsors and educate the next generation of engineering leaders in power electronics and electromechanical power conversion. Lorenz, who co-directed WEMPEC for 22 years, was internationally renowned as the world's leading authority in the field of physics-based control of electric motors and adjustable-speed drives.

Lorenz received his bachelor's, master's and PhD in mechanical engineering from UW-Madison. Before beginning his PhD program, Lorenz worked in industry for 10



years at Gleason Works in Rochester, New York, where he honed his engineering skills by developing high-performance motor controls for machine tools that were ahead of their time. He also served two years in the U.S. Army during the Vietnam War, developing new gun-aiming controls at the Aberdeen Proving Ground in Maryland.

Always known for his infectious enthusiasm and high energy level, he passionately pursued his unique research vision for 35 years at UW-Madison, where he supervised more than 200 graduate students, authored more than 400 technical papers with his students that resulted in 34 IEEE prize paper awards, and earned more than 40 U.S. patents.

Lorenz's many original contributions have significantly improved the performance of electric motors in nearly every conceivable application ranging from paper mills to electric vehicles. He was globally recognized as a pioneer in the development of robust "self-sensing" control algorithms that eliminate fragile rotor position sensors from electric motors in many high-performance applications, making the motors smaller, less expensive and more reliable. He also invented a new motor control scheme that makes motors respond more rapidly and accurately to commands while simultaneously improving their efficiency. These valuable features are highly appealing to motor drive manufacturers who are now adopting this

breakthrough control scheme in their newest generation of high-performance factory automation drive products.

Lorenz earned numerous prestigious awards during his academic career, including the IEEE Richard Kaufmann Technical Field Award in 2014, and was named an IEEE fellow in 1998. He was very active in IEEE, including service as president of the IEEE Industry Applications Society during 2001 and

an elected member of the IEEE Board of Directors from 2005 to 2006. He also held the Elmer and Janet Kaiser Chair and was Consolidated Papers Professor of Controls Engineering at UW-Madison.

In addition to his impressive academic achievements, Lorenz always reserved time to be actively involved in a wide range of civic and humanitarian volunteer service activities that included the Madison Rotary Club, Habitat for Humanity of Dane County, and international medical mission work in several parts of the world extending from Africa to Guatemala. Lorenz received the College of Engineering Ragnar E. Onstad Service to Society Award in 2002 in recognition of his many years of dedicated public service.

Two members of the UW-Madison Department of Engineering Physics advisory board also were among those elected to the NAE. Mary Baker (BSEMA '66), president, chair and one of the founders of San Diego-based ATA Engineering Inc., was recognized for computer simulation methods for structural mechanics problems and engineering leadership. And the NAE recognized Kathryn A. McCarthy, vice president of research and development at Canadian Nuclear Laboratories, Chalk River, Ontario, Canada, for leadership in research and data analysis in support of licensing extensions for light water nuclear reactors.

## FORMER DEAN AMONG ELITE ALUMNI



The Wisconsin Alumni Association's Distinguished Alumni Awards are the highest honor a UW-Madison alum can receive. For more than 80 years, the alumni association has recognized the university's most prestigious graduates for their professional achievements, contributions to society and support of the university. John Bollinger (BSME '57, PhDME '61), College of Engineering dean from 1981 to 1999, was among the 2018 honorees.

During his 18-year tenure as dean, Bollinger presided over many innovations, including a renovation of Engineering Hall and of the Materials Science and Engineering Building, as well as plans for the Engineering Centers Building—the first new engineering building in 40 years. With a strong focus on undergraduate education and opportunities, he also oversaw the launch of a new freshman course that assigned a real-world engineering project from design to final product. The college also instituted several annual competitions that encouraged students to invent, patent and commercialize their own technology.

As a faculty member, Bollinger was director of the Data Acquisition and Simulation Laboratory and served as chair of the Department of Mechanical Engineering. He was a Fulbright Fellow in 1962 and 1980 and coauthored two textbooks. Among his many patents, he invented a noise-quality detector for electric motors and an automated welder that helped Milwaukee's A.O. Smith Company in manufacturing automobile frames. He founded and served as editor of the *Journal of Manufacturing Systems*.

He has served on the boards of numerous companies, including Nicolet Instrument Corporation, Unico Incorporated, Kohler Company, and Berbee Information Systems. Bollinger is a member of the National Academy of Engineering, the American Society of Mechanical Engineers, and the American Society for Engineering Education.

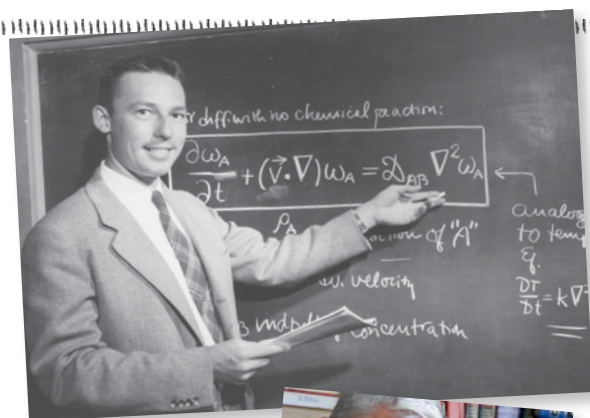
## HONORING A VISIONARY LEADER

As Professor Emeritus Bob Bird approaches his 95<sup>th</sup> birthday, the Department of Chemical and Biological Engineering is embarking on a major effort to endow the Robert Byron Bird Department Chair, honoring a truly one-of-a-kind person who has done so much to establish and nurture UW-Madison's tradition of excellence.

His scholarly contributions are legendary. His foundational textbooks revolutionized chemical engineering. And outside of the lab and the classroom, he is a linguist, a musician, a composer, a historian, a limerick writer and a puzzle creator.

Regina Murphy, the first Robert Byron Bird Department Chair, will honor his leadership and service to the department. Funds from the endowed chair will be used at the department chair's discretion to strengthen his or her ability to face the particular challenges of the day and to lead the department confidently into the future. **Read more about Bob: perspective.** [engr.wisc.edu/2014/01/in-celebration-of-decades-of-dedication/](http://engr.wisc.edu/2014/01/in-celebration-of-decades-of-dedication/)

To make a gift in Bird's honor, visit [supportuw.org/giveto/birdchair](http://supportuw.org/giveto/birdchair)



# 12 AMAZING ALUMNI YOU NEED TO KNOW

A UW-Madison engineering education provides a solid foundation for a career—and the College of Engineering continues a 150-plus-year tradition of enrolling, educating and graduating engineers of the highest caliber. When they go to work, engineering alumni excel at what they do.

At the 2018 Engineers' Day banquet Oct. 19, 2018, the College of Engineering honored 12 influential alumni who have applied their UW-Madison engineering education and experiences to make a difference in such fields academia, hospitality, law, medical technology and more. Among the 12 are six 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.

Read more about each here: [www.engr.wisc.edu/college-recognizes-12-outstanding-alumni-on-engineers-day](http://www.engr.wisc.edu/college-recognizes-12-outstanding-alumni-on-engineers-day)

## Early Career Award recipients

1

**Justin Beck**  
CEO, PerBlue  
BSCMPE '09, BSCS '09,  
UW-Madison



We honored Justin for his leadership in nurturing the Wisconsin entrepreneurial ecosystem, the state's economic development, and as an exemplary demonstrator of collaborative engineering success.

4

**Gregory Hudalla**  
Biomedical Engineering  
Assistant Professor and Pruitt  
Family Term Fellow, University  
of Florida



BSCHE '04, Illinois Institute of Technology;  
MSBME '06, PhDBME '10, UW-Madison

We honored Greg for his excellence in biomedical engineering research and education.

2

**Gilbert Haddad**  
Director, Point72 Asset  
Management  
Staff Advisor, SparkCognition  
BSME '07, American University of  
Beirut; MSME '09, UW-Madison; PhDM '11, University  
of Maryland



We honored Gilbert for his work in applying data science and analytics in ways that have increased his companies' productivity and profitability.

5

**Rahul Shinde**  
Executive Director, DIL  
BEME '99, College of Engineering-  
Pune, India; MSMSE '01, PhDI '05,  
UW-Madison



We honored Rahul as an inspiring industrial engineer and pragmatic leader who has successfully demonstrated how systems thinking and technology can transform business, upgrade customer experience and help improve lives within communities.

3

**Andrew Hanson**  
CTO, PerBlue  
BSCMPE '09, BSCS '09,  
UW-Madison



We honored Andrew for his leadership in nurturing the Wisconsin entrepreneurial ecosystem, the state's economic development, and as an exemplary demonstrator of collaborative engineering success.

6

**Forrest Woolworth**  
COO, PerBlue  
BSCMPE '09, BSCS '09,  
UW-Madison



We honored Forrest for his leadership in nurturing the Wisconsin entrepreneurial ecosystem, the state's economic development, and as an exemplary demonstrator of collaborative engineering success.



## Distinguished Achievement Award recipients

7

### Wendy Harris

**COO and GM, Commercial Operations, GE Healthcare**

BSECE '90, MBA '99, UW-Madison



We honored Wendy for her industry leadership in healthcare technologies, workforce diversification, and women's health issues.

8

### Robert J. Heideman

**SVP and CTO, A.O. Smith Corp.**

BSMetE '88, PhDMatE '15, UW-Madison; MSMetE '92, Purdue University



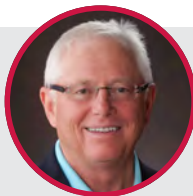
We honored Bob for advancing manufacturing technology through research, product engineering, technology management and corporate leadership.

9

### Arthur Janes

**CEO, PDS Technology**

BSME '67, BBA '67, UW-Madison



We honored Art as an accomplished entrepreneur and corporate leader who successfully founded and grew an engineering and technical staffing company.

10

### W. Kent Lorenz

**Chairman and CEO (retired), Acieta LLC**

BSEM '84, UW-Madison



We honored Kent for his dedication as a leader whose efforts to advance industrial robotic automation have led to new and improved manufacturing processes. These advancements have helped to improve quality, lower costs and increase safety for North American manufacturers. Kent's passion in industrial robotics has also inspired future generations of engineers through his work with Project Lead the Way and the Schools to Skills programs.

11

### William S. Monfre

**Engineering and Manufacturing Management, Procter & Gamble**

(1985-2008)

**President/Owner, Quality**

**Insulators Inc. and Asbestos Removal Inc.**

(2008-current)

BSChE '85, UW-Madison



We honored Bill as an engineer and entrepreneur whose expertise and creativity have enabled him to become a leader in his professional career.

12

### Brian Mullins

**Partner, Axley Brynelson LLP**

BSCEE '77, JD '80, UW-Madison



Brian passed away in February 2018.

We honored him posthumously for the instrumental role he played, both as a civil engineer and as an attorney, in developing construction law in Wisconsin.



## ‘STEALTH SHEET’ HIDES HOT OBJECTS FROM PRYING INFRARED EYES

Whether in the darkest of nights or the heaviest of fogs, a new ultrathin cloaking material can render objects—and people—practically invisible to the heat-sensing eyes of an infrared camera.

“Right now, what people have is much heavier

metal armor or thermal blankets,” says the material’s creator Hongrui Jiang, the Lynn H. Matthias Professor and Vilas Distinguished Achievement Professor of electrical and computer engineering.

Warm objects like human bodies or tank engines emit heat as infrared light, and his team’s new stealth sheet offers substantial improvements over other heat-masking technologies.

Measuring less than one millimeter wide—roughly the thickness of 10 paper pages—the thin sheet absorbs approximately 94 percent of the infrared light it encounters. Trapping so much light means that warm objects beneath the cloaking material become almost completely invisible to infrared detectors.

Importantly, the stealth material can strongly absorb light in the so-called mid- and long-wavelength infrared range, which is the type of light emitted by objects at approximately human body temperature.

And by incorporating electronic heating elements into the stealth sheet, Jiang and his team created a high-tech disguise for tricking infrared cameras.

“You can intentionally deceive an infrared detector by presenting a false heat signature,” says Jiang. “It could conceal a tank by presenting what looks like a simple highway guardrail.”

To trap infrared light, Jiang and colleagues turned to a unique material called black silicon, which is commonly incorporated into solar cells. Black silicon absorbs light because it consists of millions

of microscopic needles (called nanowires) all pointing upward like a densely-packed forest—incoming light reflects back and forth between the vertical spires, bouncing around within the material instead of escaping.

Although black silicon has long been known to absorb visible light, Jiang and colleagues were the first to see the material’s potential for trapping infrared, and they boosted its absorptive properties by tweaking the method through which they created their material.

The researchers’ black silicon also has a flexible backing interspersed with small air channels. Those air channels prevent the stealth sheet from heating up too quickly as it absorbs infrared light.

Currently, Jiang and colleagues are working to scale up their prototype for real-world applications with assistance from the UW-Madison Discovery to Product (D2P) program. They received a U.S. patent in fall 2017 for the material’s use in stealth, and the Wisconsin Alumni Research Foundation—UW-Madison’s patenting and technology licensing arm—is actively pursuing two additional patent applications.

A newly developed stealth sheet can hide hot objects like human bodies or military vehicles from infrared cameras. *Photo: Hongrui Jiang.*

