

PERSPECTIVE



ENGINEERING THE FUTURE

Through an ambitious plan for growth, our college aims to have an even greater impact through leadership





4

Headed in a new direction

Christian Franck's goal is to learn how a common ball-control technique affects athletes competing in the world's most popular sport.



6

Ground control

How engineering advances useful on Earth are laying the groundwork for future explorations in space.



8

Closing the loop

Can chemical engineering save the world from mounting plastic pollution?

11 From the Lab

College of Engineering research news

16 The Next Generation

Engineering students do some amazing things

19 Badger Engineers

Honoring elite alumni

22 Wisconsin Idea

Engineering at work in the world

PERSPECTIVE MAGAZINE

ENGINEERING EXTERNAL RELATIONS

Editor: Renee Meiller
perspective@engr.wisc.edu

Writers: Jason Daley, Alex Holloway, Adam Malecek,
Tom Ziemer

Designers: Joel Hallberg, Kristen Koenig

COLLEGE LEADERSHIP

Dean: Ian M. Robertson

Executive Associate Dean: David Noyce

Associate Deans:

Edward Borbely, Engineering Professional Development
Douglass Henderson, Faculty Development
Manuela Romero, Undergraduate Affairs
Oliver Schmitz, Research and Graduate Affairs
Cathleen Walters, Advancement
Adam Whitehorse, Chief Financial Officer

CONNECTIONS

Prospective Students
coeadvising@wisc.edu

Engineering Professional Development
epd.wisc.edu

Make a gift to the college
(608) 265-8021 • cgwalters@wisc.edu
[donate.engr.wisc.edu](https://www.wisc.edu/donate/engr.wisc.edu)

Get involved
alumni@engr.wisc.edu

Connect with the college
[t](#) [f](#) [i](#) [v](#) [in](#) @UWMadEngr



College of Engineering
UNIVERSITY OF WISCONSIN-MADISON



Greetings from Wisconsin!

In September 2020, our college received a \$32 million commitment from The Grainger Foundation—a pledge that helps us to take the next steps in exciting plans we have to expand our enrollment, recruit and reward top professors, and position the college for the future.

The largest portion of that pledge—\$20 million—established a matching undergraduate scholarship program known as the STAR (Strategic Targeted Achievement Recognition) initiative. The pledge challenges us to raise an additional \$20 million that we will use to enable talented individuals to study engineering at UW-Madison. Many thanks to all who have already taken advantage of this matching opportunity and have created a STAR scholarship.

The remainder of the pledge endowed seven new named professorships. It also named the college deanship. Given the programs and initiatives that have been made possible by The Grainger Foundation, I am particularly honored to be named the first Grainger Dean of the College of Engineering at UW-Madison.

The COVID-19 pandemic has brought many changes to our campus. Our faculty and instructional staff have been exceptional and I am very impressed with the creativity they have shown—especially in how to conduct instructional laboratories remotely. We are evaluating their approaches to determine

their impact on student learning, and will introduce the best practices broadly to improve our students' educational experience. This effort will be bolstered by the Keith and Jane Morgan Nosbusch Professorships in Engineering Education.


We also have heard students and employers when they tell us there is a need for more engineers from UW-Madison. We plan to respond by creating 1,000 new opportunities for students to study engineering. Part of this plan includes a new interdisciplinary instructional and research building on our engineering campus. This new building will provide modern, safe spaces for our students to learn and conduct research—and I hope that in the future, I will be able to report that we have received support from the state and are starting the transformation of our engineering campus.

On, Wisconsin!

A handwritten signature in black ink that reads "Ian M. Robertson". The signature is fluid and cursive, with the first letters of the first and last names being capitalized and prominent.

Ian Robertson
Grainger Dean of the College of Engineering

Dedicated to fostering the highest standards of integrity, ethics, inclusiveness, and service to society.



A teenage soccer player darts toward goal, accelerating away from a defender before leaping into the air, thrusting her head forward and thumping the airborne ball with her forehead past a helpless goalkeeper and into the back of the net. Skill, timing and athleticism converge to produce a textbook header—and a goal.

But at what cost to the player?

HEADED IN A N

By Tom Ziemer

NEW REACTION

As awareness of concussions has risen in recent decades—and, more recently, research into the effects of sub-concussive impacts—debates about the safety of heading the ball in soccer have followed.

Christian Franck, the Grainger Institute for Engineering Associate Professor of mechanical engineering, is co-leading a project with researchers in the UW-Madison School of Medicine and Public Health and School of Nursing to examine the ramifications of headers among adolescent soccer players.

Franck is hoping to pin down the answer to what he calls the “golden question”—how much strain on a neuron is required to cause a concussion—in the next year. “We’re getting super close,” he says.

It’s part of Franck’s broader quest to define the forces inflicted upon brains and thresholds for injury in concussions and other traumatic brain injuries. In addition to looking at brain strain in soccer and football, Franck is working with companies in the cycling (Trek), construction (Milwaukee Tool) and military (Team Wendy) spaces to inform helmet and hard hat designs.

Current U.S. Youth Soccer rules bar players 10 and under from heading in games and practice, while limiting the number of headers for 11- and 12-year-olds to 25

per week. But the simple fact is the effects of headers haven’t been thoroughly studied in adults, let alone adolescents.



Using a seed grant from the UW-Madison Office of the Vice Chancellor for Research and Graduate Education, Franck and his collaborators will create computer models using MRI data and outfit players ages 12-17 with protective headbands containing sensors to record data. They’ll then feed those numbers into the computer models to generate brain motion data and see whether that mechanical loading is approaching dangerous levels. As part of the grant, Traci Snedden, an assistant professor in the School of Nursing, is also leading an effort to develop cognitive assessment tests that could help tease out links between brain changes and academic performance.

“I gravitate toward hard problems,” says Franck.

GROUND CON



On July 8, 2011, the space shuttle Atlantis blasted off from the Kennedy Space Center into a cloudy sky in the last launch of the three-decade-old program.

In the 10 years since that day, NASA engineers have been developing the Space Launch System (SLS), a powerful rocket that could be the backbone for deep-space missions beyond Earth's orbit. It's an effort that involves people, industry and researchers in every state in the nation. And with work that has applications right here on terra firma, our own engineering faculty, staff and students are working to tackle the challenges of this next generation of travel to the moon and beyond.

When humans return to the moon or make it to Mars for the first time, they'll likely need vehicles to traverse extraterrestrial surfaces. That's where Dan Negrut, the Mead Witter Foundation Professor of

Mechanical Engineering, comes in. Negrut is an expert in using simulations to predict how complex mechanical systems change in time—for example, a vehicle operating on soft terrain or a vessel plowing through ice north of the Arctic Circle.

He and his students are working on a NASA project to simulate how the VIPER rover—which is scheduled for launch in 2023—will traverse the lunar surface as it searches for frozen water. They are leveraging Project Chrono, an open-source physics simulation engine developed at UW-Madison in collaboration with scientists from Italy, where European Space Agency researchers use it to simulate how a rover might travel across the surface of Phobos, one of the Mars moons.

“The gravitational pull on Phobos is 1,700 times weaker than on Earth,” Negrut says. “The question is, can rovers move in gravity that low, or are they just going to bounce? They have some interesting wheel designs that aren't like a typical cylinder. The shape of the wheel has grooves that are almost like hands or scoops that can grab granular material, which behaves differently in low gravity.”

Negrut says he sees rover simulations as vital to preparing manned or autonomous vehicles to traverse the surfaces of the moon and Mars. As those simulations improve, he can more accurately predict how such vehicles might behave with human drivers.

A manned mission in space for any length of time also will require some sort of power source, and Paul Wilson, the Grainger Professor of Nuclear Engineering and an expert in modeling

Dan Negrut,
Mead Witter Foundation Professor
of Mechanical Engineering



Paul Wilson,
Grainger Professor of
Nuclear Engineering



TROL

HOW ENGINEERING ADVANCES USEFUL ON EARTH ARE LAYING THE GROUNDWORK FOR FUTURE EXPLORATION IN SPACE.

By Alex Holloway

complex nuclear energy systems, says portable nuclear reactors could help.

It's an idea that's more plausible than you might think: In July 2020, NASA and the U.S. Department of Energy announced a call for proposals from industry partners to build a nuclear power plant for use on the moon and, eventually, Mars. In 2018, the National Nuclear Security Administration and NASA revealed KRUSTY—a kilowatt reactor that could serve as the foundation for the type of reactors used to power outposts on distant planets. "You'd need enough fissile material to keep a reaction going," Wilson says. "But once you have that, you can usually operate it at different power levels. So if you can carry and deploy that power source once you get there, it could provide you with a steady source of electricity."

As we look toward traveling deeper into space, solar sails

that gather energy emitted from the sun could help propel those journeys, says Ramathasan Thevamaran, an assistant professor of engineering physics. Solar sails aren't a new concept; some small satellites, such as the Planetary Society's Lightsail 2, use them to orbit Earth. "The idea is that you create these large mirrors made up of thin, very lightweight materials," says Thevamaran, who develops revolutionary materials for a variety of engineering applications. "If you make a mirror on one side, the sun's radiation will exert pressure on that. The amount of thrust you get is very small, but it's constant."

Such solar sails could play a role in scheduled transits; for example, says Thevamaran, they could ferry regular supply payloads to a hypothetical Mars outpost if the trips are correctly planned.

In the future, faculty, staff and students in the College of Engineering likely will focus their attention even more directly on these and other questions related to air and space: The Department of Engineering Physics has added an aerospace engineering option to its engineering mechanics major. Wilson, who is the department's chair, says this new option meets growing student demand and builds upon the department's historical astronautics option, which focuses on space. "We have an opportunity to educate students in all the skills it's going to take to do this kind of work," he says. "It allows us to look at the combination of technologies across the spectrum of things that fly. There's never been, in Wisconsin, an aerospace degree program, so we're filling an important gap to give students exposure to aerospace topics within our engineering physics program."



Ramathasan Thevamaran,
Assistant Professor of
Engineering Physics

The image shows a dense, colorful pile of crushed plastic bottles, likely PET, in various shades of clear, blue, and green. The bottles are flattened and packed together, creating a textured, chaotic surface. Overlaid on this background is a large white circle. Inside the circle, the word "CLOSING" is written in a bold, white, sans-serif font, centered horizontally and vertically.

CLOSING

By Jason Daley

THE LOOP ON RECYCLING

Can chemical engineering
save the world from mounting
plastic pollution?

Plastic is truly a wonder material. Since the earliest versions hit the market, the lightweight, flexible polymers have remade the world—sometimes literally. Plastics have revolutionized medical devices, packaging and shipping, construction, vehicle manufacturing, the toy industry and hundreds of other fields.

But the world's love affair with plastic has come at a huge cost. Waste plastic is polluting oceans and shores, clogging landfills and fostering dependence on the fossil fuels from which most plastics are derived.

There's really no end in sight. In fact, by 2040, the current plastic production of 330 metric tons per year likely will be double that number annually. By 2050, projections show that plastics manufacturing will produce 15 percent of the world's carbon emissions. One estimate even claims the mass of plastics in the ocean will outweigh fish by mid-century.



Wonder material or not, the world has a plastic problem.

Why not recycle?

While many people think of plastic as a recyclable commodity, that's not really the case. In the United States, only about 9 percent of plastic waste is actually recycled, and most of that is downcycled, or converted into less valuable plastic products.

That's because while plastic seems pretty straightforward, it is often a complex material rarely made of pure polymers. "When people see those recycling numbers—one through seven—they think it must be easy to recycle plastics," says Jeff Seay, a professor of chemical engineering at the University of Kentucky and founder of Engineers for Sustainable Energy Solutions. "But even though there are seven types of plastic, there are tens of thousands of formulations."

Manufacturers add hundreds of different chemical additives to plastic, including dyes and colorants, chemicals to block UV light and plasticizers to improve rigidity. "All of these chemical additives in the plastic make them incredibly difficult to recycle," says Seay.

So, what then?

Researchers are working on many potential solutions to solve the plastics problem. One avenue is simply developing biodegradable plastics, derived from corn or wheat starch,

which break down in landfills in a matter of months or years, versus decades or hundreds of years for conventional plastics. However, many of those plastics are still in the early stages, and it's unlikely they can replace the various types of plastics.

Other researchers are looking into plastic thermal conversion to turn common plastics like polyethylene and polypropylene into synthetic gas, which could be used to produce electricity. Other researchers are investigating pyrolysis, or heating plastics in a low-oxygen environment. That results in an oil that could be used as fuel.

The most promising solutions, however, are in chemical processing techniques that separate plastic polymers from chemical additives to recover "virgin" polymers, which then can be used over and over, creating a closed-loop recycling system similar to the way in which metals and glass are recycled.

Researchers are exploring several methods for chemically recovering polymers, some of which work best on certain types of plastic. Chemolysis uses chemicals to break apart, or depolymerize, plastics like PET and polyurethane into monomers, which can be used to produce virgin plastic. Selective solvent extraction is another promising technique

that uses solvent baths to dissolve plastics and separate specific polymers from one another.

How are we in the mix?

At UW-Madison, chemical engineers are beginning to refine some of these processes as part of a new \$12.5 million U.S. Department of Energy-funded multi-university center focused on chemical upcycling of plastic waste. Its director, George Huber, the Richard L. Antoine Professor of chemical and biological engineering, along with many other researchers in the College of Engineering, are investigating ways to make recycling easier and more cost effective.

One avenue of investigation is pyrolysis, which uses high temperatures to break down plastics and recover virgin polymers. Currently, Huber and his team are examining the components of various pyrolyzed plastics and determining what types of catalysts could be used to convert the pyrolyzed plastics into monomers. "We're providing the molecular-level information about the chemicals that you can make from pyrolysis," he says. "That gives us ideas about how we can more efficiently go back to the original plastics."

The goal, Huber says, is to eventually be able to pyrolyze mixed plastics into an oil, then catalytically convert the

oil into monomers and finally convert those monomers into virgin polymers.

College of Engineering researchers also are working on a solvent-based recycling project for multilayered plastics using a technique they call STRAP processing. STRAP uses a series of solvent washes to selectively dissolve and precipitate single plastics out from multilayer combinations of plastics. In early efforts, they have been able to separate three-layered plastics, but the team hopes to refine the technique and identify solvents to process plastics with up to a dozen layers.



George Huber

They're also investigating ways to produce biodegradable polymers that could one day replace polyethylene, which represents about one third of the total plastics market. "Chemical upcycling of plastic waste builds on decades of prior research in the Department of Chemical and Biological Engineering that has ranged from catalysis to molecular modeling to systems research to design of polymerization reactors," says Huber. "We are now applying this knowledge base to show how chemical engineering can be used to design new processes for plastic recycling."



In the future, your Airbus could fly like a Prius

As the automobiles we drive increasingly incorporate flexible fuel and all-electric or hybrid-electric technologies, engineers are turning their attention skyward. And with \$11.5 million in U.S. Army funding, our engineers are leading a multi-institutional team on a research journey that someday could fill the air with hybrid-electric planes.

For now, their focus is on military aircraft. The researchers are studying how to enable these hybrid aircraft systems to run reliably and stably on different types of fuel and in extreme environments, and they're also analyzing the benefits and tradeoffs involved with adding electric technologies to an aircraft propulsion system.

Led by David Rothamer, the Robert Lorenz Professor of mechanical engineering, the research on campus leverages the expertise of faculty, staff and students in the Engine Research Center and the Wisconsin Electric Machines and Power Electronics Consortium.

Sensing a shift in the earth

On Nov. 15, 2017, a 5.4-magnitude earthquake struck the seaside city of Pohang, South Korea. Like others, the quake was tied to a nearby geothermal power plant, but researchers think it could have been prevented.

In enhanced geothermal systems, water injected up to three miles into the earth fissures the rock and creates superheated underground reservoirs, where water heats before it's pumped back to the surface for power generation.

Rocks in those underground regions can be under large stress, either from the weight of material pushing down on them or from the collisions and extensions of rocks under plate tectonics. Injecting water can change that stress and as a result, trigger earthquakes.



Hiroki Sone, an assistant professor of civil and environmental engineering and geological engineering, and his collaborators are taking a revolutionary approach to measuring that stress. They will intentionally fracture a borehole wall by cooling it, using miniature seismometers to "listen" to the cracking. Drawing on data from several seismometers, the team hopes to be able to tell not only when the rocks fracture, but where—ultimately helping to predict and prevent earthquakes associated with enhanced geothermal systems.

Enabling a critical cancer treatment option

CAR T therapy is an emerging treatment that leverages T cells—a patient’s own “soldiers” of the immune system—to fight cancer, particularly in people who are running out of options.

In the treatment, T cells are removed from the patient’s body, engineered into cancer-targeting super-soldiers, then reinjected into the patient.



Biomedical Engineering Professor Melissa Skala and her students can use optical imaging techniques they’ve developed to reliably identify activated immune T cells based on metabolites glowing faintly within them. That’s important for helping doctors answer questions about whether patients have enough healthy immune cells and whether they are likely to benefit from this last-line therapy. Now, Skala and her collaborators are working to commercialize their techniques.



How fluid dynamics researchers are breaking down a deadly blood disease

Sickle cell disease causes red blood cells to stiffen and become sickle-shaped. This painful disorder affects 70,000 to 80,000 Americans per year, primarily African Americans and Hispanic Americans, and comes with a host of complications, including anemia, organ damage and inflammation.

Today, people with the disease often live into their 40s. But there is still more progress to be made, and Michael Graham, the Vilas Distinguished Achievement Professor and Harvey D. Spangler Professor in chemical and biological

engineering who models cell movement in the bloodstream, is illuminating some of the answers.

He and his students have learned that when stiffer cells, like white blood cells and platelets, collide with red blood cells, they’re driven toward blood vessel walls in a process called “margination.” He and his collaborators also found that margination also happens with sickle cells and ultimately, activates inflammatory signals.

Graham hopes that understanding will help researchers find new treatment methods for the disease.



For spintronic devices, the movement continues

A new x-ray technique has unlocked the magnetic secrets of nanoscale spintronic devices.

For our daily lives, next-generation spintronic devices can help make our electronics smaller, faster and more energy-efficient.

Understanding and controlling magnetism is key to developing these new spintronic devices, and Materials Science Engineering Professor Paul Evans and Assistant Professor Jiamian Hu and their graduate students were part of an international team seeking to understand their magnetic properties.

The team created a spintronic device, then used the European Synchrotron Radiation Facility in Grenoble, France, to image it—but in a unique way. Rather than x-ray it directly, like an ER doctor might do with a broken bone, the team used hard x-ray nanobeam diffraction techniques to probe all the layers of the spintronic device at once. What they saw and learned will change how the devices are modeled and designed in the future.

Processing improvements

Leveraging microorganisms, a team of chemical engineers has developed a process that in the future could produce an array of sustainable chemicals from biomass.

It starts with levulinic acid, a biomass-derived five-carbon organic acid that can become a platform precursor to biofuels and other chemical products, and a bacterium called *Pseudomonas putida* KT2440 that can “eat,” or process, the acid and use it to produce more cells.

With his students and colleagues, Brian Pfleger, the Jay and Cynthia Ihlenfeld Professor of chemical and biological engineering, identified specific genes that enable this ability and learned how they processed levulinic acid. Using the well understood “model” organism *E. coli*, they tested its ability to turn those genes on

and off and effectively convert levulinic acid into methyl ethyl ketone.

Otherwise known as butanone, it’s a common industrial petrochemical solvent—and among many chemicals that could be made through the process.

Pfleger hopes this metabolic engineering will be a sustainable paradigm shift for producing commodity chemicals. “In a petrochemical refinery, you have a list of compounds that are in the barrel of oil, you do some reactions, and you make some chemical conversions. But basically, what you’re trying to do is find a use for every single one of those molecules,” he says. “Here, we’re starting with sugar, or in this case levulinic acid, and we can go to virtually any molecule a cell could make.”



Engineering afield

Electrical and Computer Engineering Assistant Professor Bhuvana Krishnaswamy is part of a team that's developing wireless underground sensor networks as part of an effort to make transformative advances in our understanding of soils. That knowledge could lead to revolutions in agriculture, soil science and ecosystem research.



The team is developing wireless algorithms for sensors that will be deployed in a test bed constructed at Argonne National Laboratory. Krishnaswamy, who researches wireless networks, will apply her expertise through communication algorithms that are low-power and traverse through soil and air over long distances. "The soil macroscope project will provide a deeper understanding of soil's biogeochemistry through orders-of-magnitude improvements in the size and resolution of collective soil data. Its end-to-end underground sensor networks will gather soil data in real time, at root zone depth, and at high spatiotemporal resolution," she says.

Phone tree

The near future of flexible electronics promises gadgets like paper-thin displays or tablets that can roll up.

And Zhenqiang "Jack" Ma, Lynn H. Matthias Professor and Vilas Distinguished Achievement Professor of electrical and computer engineering, and his collaborators are using an inexpensive, sustainable substance—wood—to make the flexible microwave circuits that could power those futuristic devices.

For their substrate, they used cellulose nanofibril paper, a strong, flexible, transparent and biodegradable film made from wood fiber. Then, rather

than layering that entire substrate with expensive gallium nitride (currently the highest performing microwave transistor material), the team used just a speck of the compound.

The resulting flexible circuit is sustainable and effective: It can output 10 milliwatts of power beyond 5 gigahertz, and the cellulose nanofibril substrate is just as compatible with the microwave components as polyethylene substrates. And, Ma says, beyond microwave applications, it could be useful for all sorts of flexible electronic components.



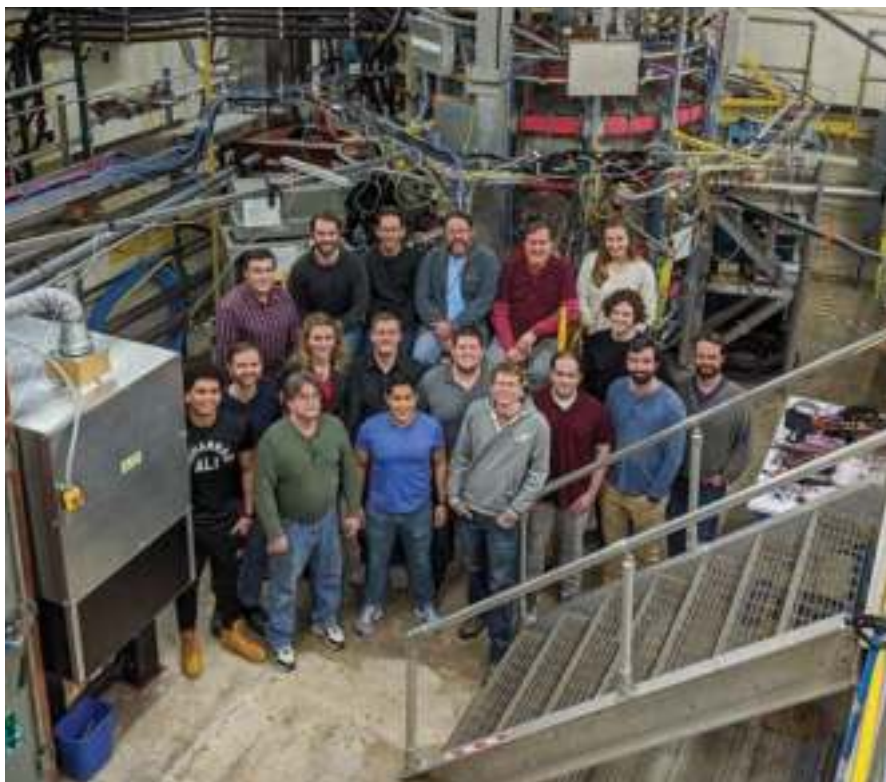
Caregiver connections

Across the United States, 16 million people provide unpaid care for individuals with Alzheimer's disease or other dementias, and the work of these informal caregivers adds up to more than 18.5 billion hours each year.

This caregiving is a responsibility that starts with the best of intentions but often slides into feelings of frustration, isolation and burnout. A team led by Nicole Werner, Harvey D. Spangler assistant professor of industrial and systems engineering, has studied this work. She and her students

are developing interventions to support those caregivers, reduce their stress, help them work more effectively alone and with other caregivers, and ultimately, to provide the best care possible.





New fusion era takes wing

For more than two decades, UW-Madison engineers have leveraged resources, expertise and a unique experiment called Pegasus to advance fusion energy and plasma science and establish themselves as world leaders in the field.

Now, with a major reconfiguration, Pegasus-III will play an even greater role in the nation's fusion research program, providing a dedicated U.S. platform and proving ground for studying innovative techniques for starting a plasma, the ultra-hot ionized gas that releases energy in a fusion reactor. "In a sense," says Engineering Physics Professor Emeritus Ray Fonck, "we're working to provide a match to light the fusion fire in future reactors."

Also drawing on the expertise of Stephanie Diem, who recently joined the Department of Engineering Physics as an assistant professor, Pegasus-III researchers will test a handful of the most promising concepts and implement the best solution on the larger national experiment at the Princeton Plasma Physics Laboratory.

UW-Madison is a great place for this next step for fusion, says Fonck. "We have the expertise on this technique and an existing facility that can be converted to this opportunity," he says. "It's cheaper and more flexible—and it gives a wonderful opportunity for students to get an education and to work with people from other labs."

What blood flow says about the hearts of men and women

Our hearts might hold many secrets, but an imaging technology called 4D flow MRI is enabling our engineers to see when they are broken.

Alejandro Roldán-Alzate, an assistant professor of mechanical engineering, postdoctoral researcher David Rutkowski and their collaborators have used the technology to identify significant differences in blood flow in the hearts of healthy men and women. They documented, in real time, blood flow characteristics such as speed, twists and turns, as well as differences in cardiac performance between sexes—all of which will help them establish quantitative standards for what's normal for each sex.



The technology also allowed them to reach beyond what's currently possible in clinical assessments. "Our goal is to use existing technology to develop new ways of determining how sick a patient with cardiovascular disease is," says Roldán-Alzate. "These methods also allow us to assess the effectiveness of a treatment or surgery for improving a patient's heart function."

THE NEXT GENERATION

ENGINEERING STUDENTS DO SOME AMAZING THINGS



Board teachers

Civil and environmental engineering undergrads Joel Baraka and Anson Liow have invented 5 STA-Z, a board game for students in Africa—particularly those in refugee camps—that literally turns learning into fun.

The game incorporates core curriculum subjects taught in Uganda—math, science, social studies and English—and breaks them down into easy-to-understand parts. “It’s collaborative and competitive, and something we want to be fun and engaging,” Baraka says.

It’s also very personal. Baraka was born in the Democratic Republic of Congo, but his family fled to Uganda’s Kyangwali Refugee Settlement to escape civil war in his home country. He grew up in the camp, where he completed his primary education before attending high school at the African Leadership Academy (ALA) in South Africa. “In a refugee camp, there aren’t many resources that children can use,” Baraka says. “They rely on teachers as the main form of learning. Classes can have up to 200 children, and that can be very frustrating for students and teachers.”

While in high school, Baraka occasionally returned to Uganda to see family. When he visited his old primary school in the refugee camp, he noticed that kids in the back of the room would often lose focus and play among themselves. “Even during breaks when they were not having class, I could see them inventing simple games and just playing,” he says.

That sparked the idea for 5 STA-Z; played in groups of five, it makes learning more engaging. “My hope is that when children use this game, they will become ‘stars,’” he says. “They are learning and becoming its stars as they master the content. When you look at the name, it’s ‘five stars,’ but it’s spelled with ‘A-Z’ because I wanted to create a game that covered the full curriculum of Uganda.”

Through their startup company, My HOME Stars, the team has produced more than 200 games to support two primary schools in the Kyangwali Refugee Settlement. The two now are working with a Ugandan producer to manufacture it.

Space shield

Students in the fall 2020 freshman design course took on a real-world project that may enable us to explore a whole new universe. “Our goal was to design a magnetic shielding device for spaceships for long space travel to Mars,” says first-year nuclear engineering student Charlie Erickson. “The shield is to protect against solar radiation.”



For their project, the students learned about the physics of solar radiation and space travel. They discussed potential solutions, developed a design, and built a small-scale prototype for their client, Paolo Desiati, an astrophysicist at UW-Madison who has funding from NASA for the shielding project.

They also learned what it’s like to work on an engineering project in a group. “Beyond learning the hard skills like chemistry or math, I’d argue it’s more important that we’re learning those soft skills like communicating with a team,” says biomedical engineering student Raad Allawi. “We’re learning to work together and listen to different ideas to build a better project. It’s a unique experience, but it’s an essential one. If you’re an engineer, you’re never really working alone.”



Kitchens, cupcakes, cookies and chemicals

For many undergrads participating in CBE 424, the chemical and biological engineering capstone course popularly known as “summer lab,” it’s a chance to apply everything they’ve learned over the last few years.

The intensive course is a taste of life as a chemical engineer; students work full time for five weeks in an Engineering Hall laboratory performing experiments and running pilot-scale industrial equipment such as distillation columns and heat exchangers. They do formal group experiments on chemical process equipment and, in teams of two, perform a series of self-directed informal experiments. They spend evenings and weekends writing up technical reports on those experiments. To support their work, students have access to a well-equipped stockroom and to an analytical lab with equipment like gas chromatographs.

In spring 2020, however, as the reality of the COVID-19 pandemic set in and campus closed, students and faculty began to wonder if they would be able

to experience this “rite of passage” held every summer since 1948.

Undaunted, they made lemonade out of lemons, and their virtual summer lab centered around the kitchen—a room that is the center of almost every home.

CBE staff filled and distributed (safely, in person, or via mail) more than 100 boxes for students’ kitchen laboratories. Their contents included thermocouples, a scale, a pH meter, a total dissolved solids meter, activated charcoal, sand, coffee filters, and other items that students might need to design and perform experiments.

Not surprisingly, many chose food-science based experiments, working with cookies and cupcakes, sweet potatoes, orange juice and other items they could grab or order from the grocery store. “Our students did some really good science,” says instructor Jim Miller. “There were a number of different, inventive and scientifically rich experiments.”

One team built a sophisticated heat exchanger using plastic bottles and PVC

tubing included in their box. Others examined heat transport by baking sweet potatoes. One examined the effects of ingredient changes on the browning, height, volume and density of sugar cookies, then used cellphone cameras to evaluate cookie color. Another team mimicked a Rockwell hardness tester using a drill bit, a small basket and some quarters.

For their formal experiments, students analyzed real data sets from previous summer lab sessions and wrote technical reports based on their results.

All in all, students report working the same long, intense hours as those in previous in-person summer labs. And while the class of 2020 learned differently, the experience was just as rigorous. “I think we got a different set of skills than previous graduating classes,” says student Sahana Walter. “But that’s the heart of engineering. Not everything in life is ideal and you have to make do with the resources you’re given.”



THE NEXT GENERATION

ENGINEERING STUDENTS DO SOME AMAZING THINGS

Building opportunities

In 2020, civil and environmental engineering senior Dalila Ricci earned the Alliant Energy/Erroll B. Davis, Jr. Academic Achievement Award, an annual honor that recognizes the academic and community service of engineering and business students from traditionally underrepresented groups at UW-Madison and UW-Platteville.



Ricci, who is focusing on construction engineering and management, has held internships in road construction, as well as with J.H. Findorff & Son in Madison on a project to build the Exact Sciences Discovery Campus on the city's west side. In summer 2020, she also worked on the Pier 26 project in New York City, which opened to the public in fall 2020. "All of these projects have been incredibly fulfilling," she says.

Beyond her work in the field and in the classroom, Ricci is active across campus. She is involved with the Wisconsin Union Directorate, is an events director for the Senior Year Office, and works as a tutor through the Leaders in Engineering Excellence and Diversity scholars. She's also a member of the Society of Hispanic Professional Engineers and now is its internal vice president. "I've been mentored and get to be a mentor now," she says. "We have this vision of underrepresented minorities succeeding in STEM, and having that ideal personified in that organization is why I'm a part of it. That's the organization I'm proud of because I've been in it since the very beginning and I've grown so much because of it."

Ricci plans to graduate in May 2020. She has already secured several job offers and is in the process of determining where she wants to live as she starts her career as a project engineer. Further down the line, she says she'd like to pursue an MBA to round out her skillset as an engineer and business leader.

Undergrad among world's intellectual elite

Senior Alex Plum was among finalists for the Rhodes Scholarship, the oldest and most celebrated college award for postgraduate international study. He is earning a double major in mathematics and engineering physics, with honors in the liberal arts and certificates in physics and computer science.

Beyond those formal academic pursuits, Plum has received a Wisconsin Academic Excellence Scholarship, a four-year, partial-tuition scholarship for top Wisconsin high school graduates, as well as more than a dozen scholarships, including a Sophomore Research Fellowship and a Hilldale Research Fellowship, UW-Madison's top undergraduate research awards. Since his freshman year, Plum has worked with Botany Professor David Baum on research projects investigating the origins of life. He also has sought numerous off-campus research

opportunities. In summer 2018, he worked with a team of ecologists in Uruguay to develop computational models to investigate the effects of



environmental policy on a water reservoir. During spring and summer 2020, he worked with physical biologist Christopher Kempes, a professor at the prestigious Santa Fe Institute, the world's leading research center for complex systems science.

He's also a tutor through the engineering Undergraduate Learning Center, volunteers with a science outreach program, and is president of the Socratic Society, a philosophy club where students discuss topics at the intersection of philosophy, the sciences, and current events.

Aero update

In summer 2021, a new, sleek cutting-edge aircraft will take its maiden voyage in the skies over Madison, when the DarkAero 1 begins test flights at the Dane County Regional Airport.

But the jet-black two-seat prop plane could just as easily be called the BuckyAero. The aircraft's designers are three brothers—Ryley, Keegan and River Karl—all of whom graduated from the College of Engineering and are intent on disrupting the kit aircraft industry.

The Karl brothers grew up hearing stories about airplane construction from their grandfather, an engineer at Boeing, and they spent long hours putting together model airplane kits as kids. The three had always talked about going into business together, but as they graduated from college, they got jobs with different companies in different industries.

In 2011, Ryley (BSEM '08) rejoined his brothers in Madison after working in hydraulic systems R&D for Caterpillar in Decatur, Illinois. He brought with him a kit aircraft he'd been putting together for fun. In their spare time, Keegan (BSME '10) and River (BSEE '12) pitched in to help build the plane. As the aircraft slowly came together, the brothers realized that many of the materials and designs in the kit were outdated or could be improved using modern engineering tools.

That also was the case for other kit aircraft designs they researched—and none of those filled the long-range, high-speed niche. "Because of our broad coverage in mechanical, aeronautical and electrical engineering, we thought we could do something very interesting," says Ryley. "I'm not sure who suggested it, but we started talking about developing our own kit. There wasn't anyone in the market doing long-range, high-speed aircraft."



The brothers believed that by using modern manufacturing techniques, they could drop the price point of their kit plane while also improving its performance over other kits in the market.

Initially, they worked nights and weekends putting together plans for DarkAero, then in 2017, they quit their day jobs and began working full time on the project at a rented hangar at the Dane County Regional Airport.

While modern aerospace firms use some of the most sophisticated engineering tools available, the brothers say that those high-tech processes have not trickled down to amateur aircraft. "The designs on the market were implemented one, two or three decades ago using the best tech at the time," says Ryley. "But there hasn't been a fresh attempt using all new tech. That's a big part of what we're doing, taking these new tools and improving home-grown aircraft to push the industry forward."

Those tools include using CAD and 3D modeling to develop the plane and simulation tools to model the designs using computational dynamics and virtual wind tunnels. The brothers are also using state-of-the-art CNC machines to cut out parts and make dimensionally accurate molds. They've used 3D printing to create some specialized parts. The plane itself has an infusion-molded frame made of composite materials—unique in the kit aircraft world—which in the past would have required a multimillion-dollar autoclave to produce.

The result of the advanced design process and materials is a plane that will be faster, lighter and more efficient than anything currently on the market. The DarkAero 1 has a 23-foot wingspan, a cruising speed of 275 miles per hour and can fly 1,700 miles.

If it hadn't been for their education at UW-Madison, the brothers say DarkAero wouldn't exist. Keegan says several lab courses he took apply directly to his daily work creating engine mounts and molding composites. His extracurricular participation on the hybrid vehicle team at the university also gave him hands-on experience in wiring the plane. Ryley says his entire undergrad experience, which included calculating airplane performance, working with wind tunnels and even designing an airplane for his senior project, laid the groundwork for the DarkAero 1. River believes that exposure to the tools and software used in modern engineering during their undergrad years gave them an edge. "If you don't have that, you don't even know these tools exist," he says. "We were exposed to skills that we didn't have to learn on our own."

The preliminary designs for the plane have convinced the hobbyist community that the DarkAero is the real deal, and the company currently has more than 40 deposits for aircraft. The three brothers plan to build the \$79,900 kits themselves, producing a handful the first year, then double production the year after, hiring more labor as they perfect their manufacturing processes.

Our college has approximately 50,000 engineering alumni, and each one of your careers has taken unique turns. One thing you all have in common is that your education has prepared you to respond to whatever challenge or opportunity comes your way. We're proud of each one of you, and we wanted to share just a few examples of your achievements. While we couldn't gather in person for our annual Engineers' Day celebration on Homecoming 2020 weekend, we honored the following alumni with college awards in 2020.

Early Career Awards



Subbu Rama
MSECE '05,
Founder,
Accio Ventures

A visionary and entrepreneurial leader in technology innovation, including pioneering virtualization of hardware accelerated devices.



Karien J. Rodríguez, Ph.D.
PhDBME '10,
Research technical strategist—
life sciences, global research &
engineering,
Kimberly-Clark Corp.

A biomedical engineer who is shaping the personal care industry through her creative and innovative research.



James Tamplin
BSIE '06, MSIE '07,
Founder partner,
Founder Collective

A systems engineer and entrepreneur who has fundamentally transformed and greatly simplified mobile and web applications development.

Distinguished Achievement Awards



Michael F. Conway
BSChE '78,
Retired president,
Shell Trading, Royal Dutch Shell

A chemical engineer who rose to the top of the international oil trading business while serving as an exemplar for management practices that reflect his values of integrity and civic responsibility.



Steven R. Erbstoesser
BSMineE '74, MSMineE '75,
Owner,
Global Operations &
Management Advisors LLC;
retired, ExxonMobil

An engineer, scientist and executive who has transformed organizations and led global teams to achieve world-class safety, operational, and business performance in oil and gas operations.



Peter Holsten
BSME '72,
President and managing broker,
Holsten Real Estate Development
Corporation

A mechanical engineer and humanitarian who is devoted to the principle that everyone deserves affordable, quality housing and who strives to build and maintain healthy communities.



Todd Kelsey
BSEE '87, MSEE '89,
President and CEO,
Plexus Corp.

An exemplary leader of a Wisconsin-based company who demonstrates commitment to creating new technologies and innovations that make a profound impact in people's lives.



Laurie Lindborg Parsons
MSCEE '87,
Water resources division director,
Ramboll US

A respected civil and environmental engineer, leader and advocate for clean water who has been a role model for women in STEM.



Jeffrey Rotsch
BSIE '72,
Retired president, worldwide sales,
General Mills

An industrial engineer and visionary leader who drove global business success in the consumer foods industry.



Oscar Marcelo Suárez
MSMetE '93, PhDMetE '00,
Professor and coordinator of the
materials science and engineering
program,
University of Puerto Rico-
Mayagüez

A metallurgical engineer who has led innovations in university education, promoted STEM, and advanced research on composite materials and nanotechnology.



Amy Warner
BSEM '91,
Vice president and general manager
of IT digital business solutions and
corporate director of accessibility,
Intel Corp.

An IT leader whose professional adaptability and commitment to empowering those of all abilities make her an example for future engineers.

COVID-19: 15 WAYS WE MADE A DIFFERENCE IN 2020

When it became clear that there were urgent needs as the COVID-19 pandemic unfolded in the United States in the early part of 2020, not only did our engineers continue their research and teaching—but, in the spirit of the Wisconsin Idea, they also rushed to help. Throughout the year, they continued to respond and innovate. Though there are more examples, here are 15 ways we contributed.



1 With campus and industry partners, we pioneered an open-source face shield now in use by millions of people worldwide, as well as a follow-up version with fabric that cinches around the jawline.

2 We created an automated online platform to help connect face shield buyers with suppliers.



3 Alum Tyler Vermey navigated the aftermath of an earthquake and a raging blizzard on a journey from Utah to Madison to contribute his expertise in ventilator design to GE Healthcare.

4 We partnered with the university's Field Day Lab to develop fun, educational materials science video games for middle and high school students.

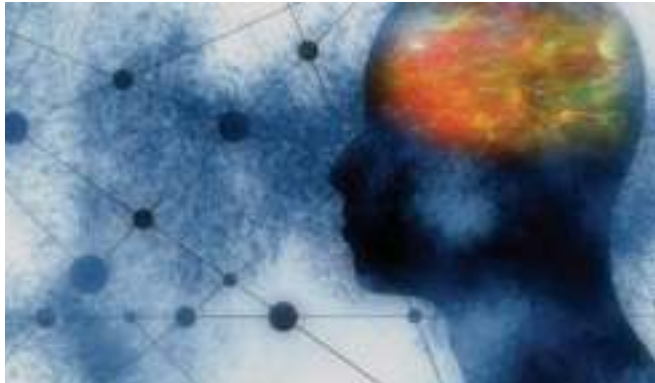


5 An industrial engineer who specializes in modeling infectious diseases worked closely with local and state health leaders to develop COVID-19 prediction models and also has been widely quoted in local, state and national media.

6



We were part of a team that worked to develop a quick, low-cost saliva-based COVID-19 testing method.



7 Researchers in our Center for Health Enhancement Systems Studies helped support healthcare providers who needed to shift quickly to telehealth visits for everything from regular checkups to mental health and substance abuse services.

8

A chemical engineer and partners in the Wisconsin Institute for Discovery received funding to study how coronaviruses enter cells, spread and cause varying immune responses in different people.



9 A civil and environmental engineer leads the Wisconsin State Laboratory of Hygiene, which has played a leading role in testing efforts during the pandemic.

10 An industrial engineer who specializes in risk analysis shared her expertise in a Badger Talks video and was widely quoted in local, state and national media about what drives pandemic-related decisions such as stay-at-home and mask-wearing orders.



11

Alum James Tamplin and collaborators developed covidactnow.org, a heavily accessed website that strives to provide timely and accurate local and state COVID-19 data.

12

We studied various mask materials, created videos that demonstrate how effectively each material and mask style contains virus particles, and with partners across campus, designed a three-layer spun-bond polypropylene material for reusable masks.



13

One of our graduate students led a large-scale United Nations-backed effort to mobilize personal protective equipment production in developing countries worldwide.

14

Engineering researchers in the Wisconsin State Laboratory of Hygiene and collaborators at UW-Milwaukee are tracking COVID-19 through its genetic fingerprint in human waste.



15

We pioneered an easy DIY mask fitter that helps to create a better seal around the edges of your face mask.





College of Engineering
UNIVERSITY OF WISCONSIN-MADISON

1415 Engineering Drive, Madison, WI 53706



Nonprofit Org.
U.S. Postage
PAID
Madison, WI
Permit No. 658



*Support the College of
Engineering on April 6-7*

dayofthebadger.org

In CEE/GLE 291, *Problem Solving Using Computer Tools*, and its associated hands-on lab section, students learn basic physical computer programming skills and, crucially, how to use land surveying equipment like levels and total stations. Early in fall 2020, while the weather was still mild, they met safely outdoors. Later in the semester, they turned to tools such as Arduino prototyping boards to learn how to use computing skills in conjunction with equipment that's often used in civil engineering.

