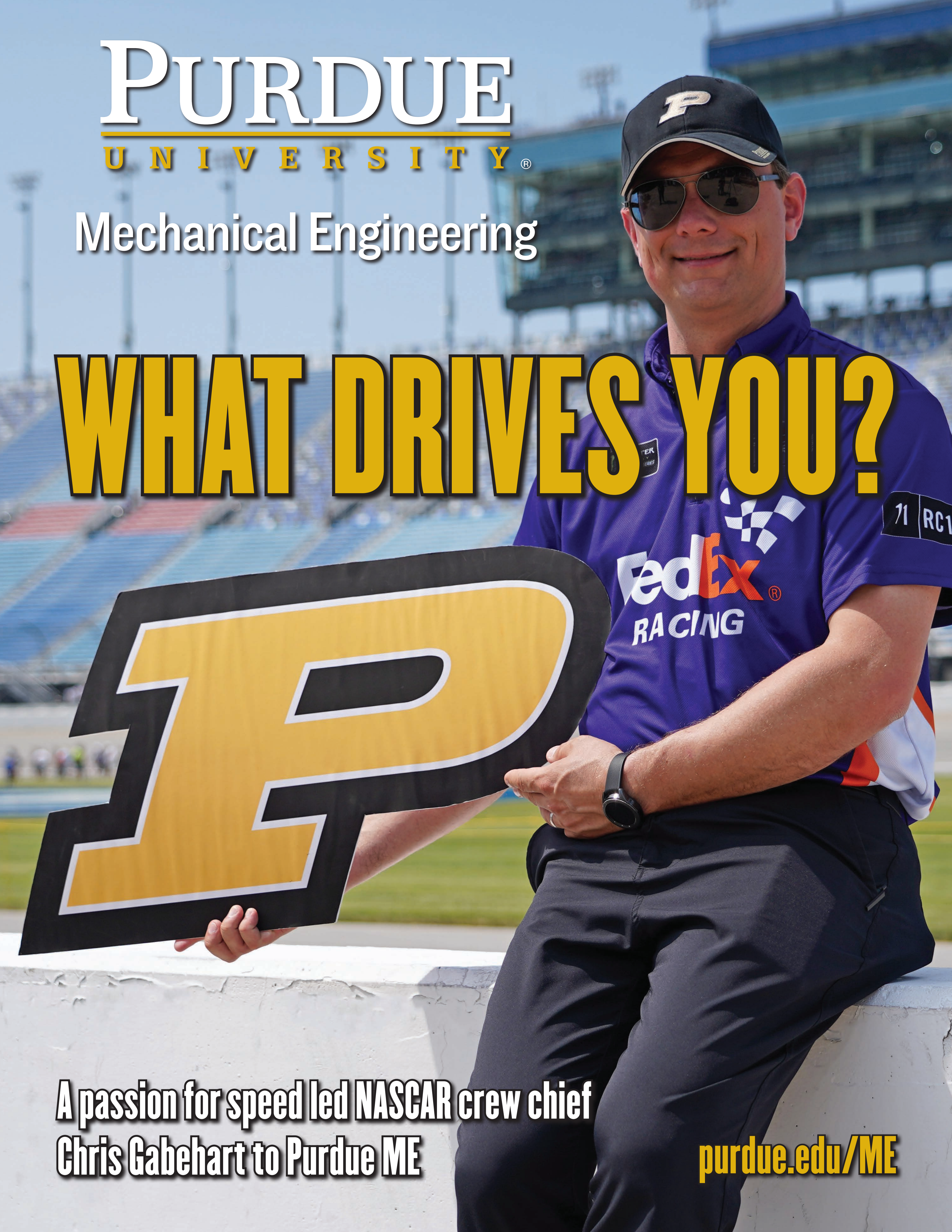
PURDUE UNIVERSITY®

Mechanical Engineering

WHAT DRIVES YOU?



A passion for speed led NASCAR crew chief Chris Gabehart to Purdue ME

purdue.edu/ME

A NEW ERA

Hello friends, my name is Eckhard Groll, and I am honored to serve as the new head of the School of Mechanical Engineering. Anil Bajaj stepped down from the position in July 2019, after nine years as head of the school. We are all deeply grateful for his leadership, and we're also glad that (after a well-earned sabbatical) he will continue to stay on campus to serve as a faculty member.

A little bit about my background: I came to Purdue in 1994 as an assistant professor, after earning my doctorate in Germany. Most recently, I served as associate dean for undergraduate and graduate education for the College of Engineering, striving to make our school a unique entity that provides exceptional cross-disciplinary and transformational learning, discovery, and engagement activities for our students, faculty and staff.

I'm also heavily involved in research, specifically about compressors, refrigeration, and energy conversion. Every two years, I chair a conference at Herrick Labs that hosts more than 800 industry experts in HVAC and High Performance Buildings. I've also been involved in converting old houses in West Lafayette into research testbeds. For example, we joined forces with the Whirlpool Corporation to create the ReNEWW House, retrofitted with renewable technologies to be net-zero energy, water, and waste. We're currently converting another house to run exclusively on DC power.

These are exciting times to be Purdue Mechanical Engineers! Every year, our school welcomes 1,400 undergraduate students and 600 graduate students to tackle the world's grand challenges. With technology developing at an exponential rate, the opportunities of becoming an engineer have never been greater. From traditional industries like the automotive world come amazing alumni like our cover subject, NASCAR crew chief Chris Gabehart. The new industries of today's space race have Purdue footprints all over them. And within the emerging fields of nanotechnology and biomedicine are future industries we can't even imagine! But we know our Purdue ME students, faculty, and alumni will be at the forefront.

I am deeply honored and excited about the opportunity to lead our school. Boiler up!

Eckhard Groll
William E. and Florence E. Perry Head of Mechanical Engineering, and Reilly Professor of Mechanical Engineering

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LIVING IN SPACE

Making Resilient Extra-Terrestrial Habitats

We've all seen TV shows or movies that show people living in futuristic space bases on the Moon or Mars. But professor Shirley Dyke says those depictions aren't very realistic. "The biggest issue for humans living in space is the hazards we have to deal with," she says. "Meteoroids, radiation, extreme temperature changes, and even seismic activity – these are all dangers that we need to prepare for."

Shirley is the head of the RETH Institute (Resilient Extra-Terrestrial Habitats), a Purdue-based interdisciplinary research group. RETH recently received a $15 million grant from NASA to research solutions to the dangers faced in future space-based habitats.

"We are tackling the problem in three ways," says Dyke. "First is resilience: building habitats that can withstand these dangers. Second is intelligence: having a network of sensors that can accurately monitor and detect what's happening. And the third is autonomy: enabling robots to fix any problems, whether humans are physically present or not."

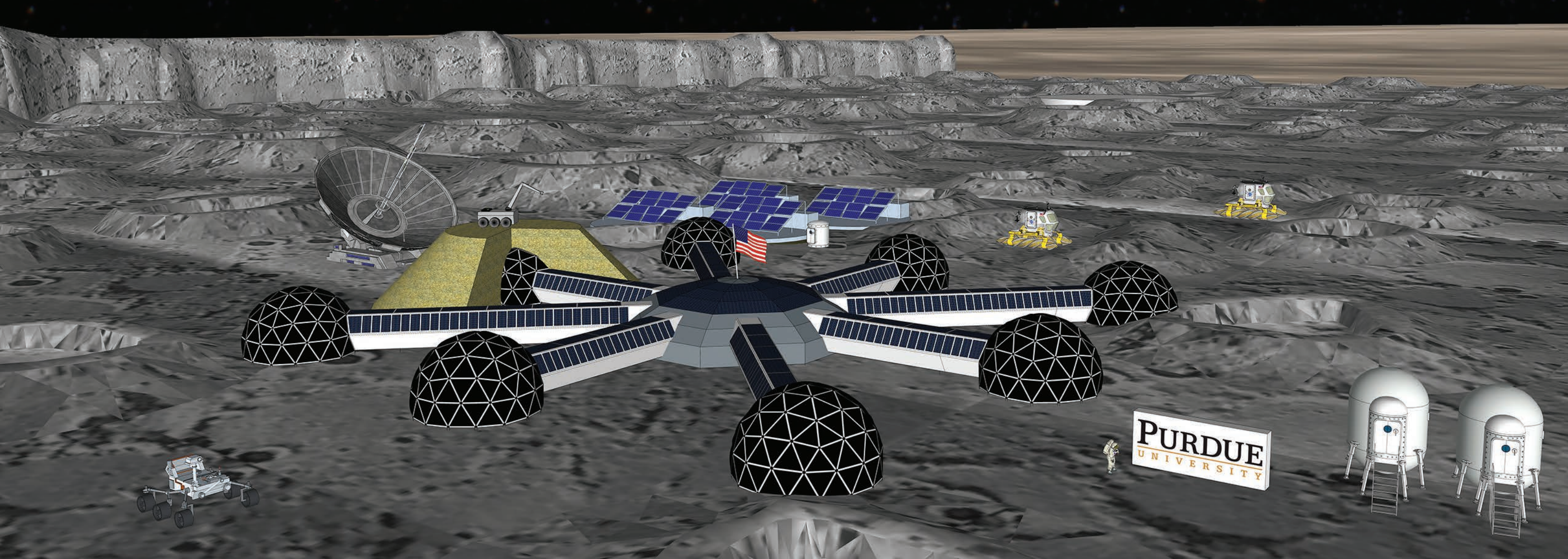
As part of the research, the RETH Institute will build a quarter-scale habitat at Herrick Labs. This structure and its various subsystems will allow some components to be physically tested, while others are examined in a virtual context. "The idea is we can swap pieces in and out to examine different aspects of the habitat system," she says. "We can look at the interactions among the subsystems and understand how to make them robustly perform the way they need to."

Their research has also involved investigating lava tubes, the underground caverns left behind after volcanic eruptions. Lava tubes on the Moon or Mars could potentially provide protection from radiation and meteor strikes.

Not every habitat will have a continuous human presence. For example, NASA's current plans for a Lunar Gateway space station involve human occupancy only for brief periods; all other times, robots will attend to the station and its research. "That's why intelligence and autonomy are so important," says Dyke. "When humans show up, the habitat has to be ready for them."

The RETH Institute includes mechanical engineering, civil engineering, aeronautical engineering, electrical engineering, earth science, and robotics.

"The ultimate goal of space travel is to serve humanity," says Shirley. "Preparing these resilient habitats in space will help us create more robust habitats here on Earth."



VICTORY LANE

Crew chief Chris Gabehart brings Purdue expertise to NASCAR

The pressure couldn't be any higher: your first race as a top-level crew chief, and it's the Daytona 500. Your driver takes the lead, and manages to avoid crash after crash. How can you keep your team focused on the finish line in front of more than 100,000 fans?

Actually, high-pressure scenarios like this are no big deal for **Chris Gabehart** (BSME '05). After all, if you can graduate from Mechanical Engineering at Purdue, you can accomplish anything!

"Graduating from Purdue was the hardest thing I've ever done," admits Chris. "And I say that proudly! They pushed me so hard to succeed at something I really wasn't good at academically, while balancing so many other things. Once I left Purdue, I realized there wasn't a mountain I couldn't climb."

Like many motorsports enthusiasts, Chris' journey in racing began at an early age. As a 10-year-old, Chris drove go-karts competitively in the World Karting Association, eventually winning several national championships. His entire family would drive an RV from their Louisville, Kentucky home and support Chris in races across the country.

But they also encouraged Chris to think about his future. "None of my family ever graduated from college," says Chris. "So from an early age, my parents pushed the importance of education, versatility, and developing a career. Racing was my passion; it was what I wanted to do. But it was only logical that I should look into furthering my education, and since race cars are engineering-based, mechanical engineering was a perfect fit."

Choosing to attend Purdue also had the benefit of being close enough to Louisville that he could still race on the weekends. "I admit I was a Monday-through-Friday student," says Chris. "In the racing world, if you don't use it, you lose it. So I continued to drive late-model races on the weekends, and went to class during the week."

While juggling a racing career with an academic career sounds overwhelming, Chris says that having a singular focus actually helped him in the classroom. "Most students don't really know what they want to do in their careers," he says, "but because I already had that passion for racing, I could see how things like thermodynamics and heat transfer applied to a race car. I sat in many lectures where I would say, 'Wow... that is going to help me in racing.' And it has!"

He also learned the vital art of problem-solving. "Purdue taught us how to think," he says. "In the racing world, no one ever 100% knows all the answers. If they did, all 40 cars would be competing for a win! We use science to make the best educated guess we can."

"Purdue is the biggest reason I'm here today, no doubt about it."

-Chris Gabehart

Through his time at Purdue, Chris continued to have success as a driver, even winning the CRA Super Series championship in 2007. But he and his family reached the point where driving alone could no longer support him financially. That's when he began transitioning into the business side of motorsports. "Through my late-model racing, I became friends with Tom Busch, who is Kyle Busch's dad," says Chris. "He liked what I was doing, and convinced me to come to work as an engineer for Kyle's late-model team. I knew those late-model cars really well, so it was a perfect way to get my feet wet as an engineer. Then in 2012, I made the move to Joe Gibbs Racing to work on his Cup car."

As one of the most stable and supportive teams in NASCAR, Joe Gibbs Racing offered Chris an environment where he could thrive. He served as crew chief in the Xfinity Series, the second level of NASCAR, winning nine races in the series. Then in December 2018, Chris became the crew chief for Denny Hamlin, a veteran driver in the top-level Monster Energy NASCAR Cup Series. Was Chris nervous about the taking the big chair? "Yes, it is a bigger stage," he laughs. "But as Tom Busch told me, 'They're still race cars; they've got four tires, and the driver sits to the left of the driveshaft.' Whether you're driving go-karts or stock cars, racing is racing. I've spent my whole career preparing for this, and I'm enjoying the challenge of it."

NASCAR's biggest annual event is the very first event of the season: the Daytona 500. The 2019 race was also the first opportunity Chris had to show he was up to the task of leading a team at the highest level of stock car racing. "Joe Gibbs Racing is tremendous," says Chris. "Their support network allowed me to compartmentalize and focus exclusively on the team, and making sure we accomplished everything we needed to leading up to that race. It's also awesome to have Denny Hamlin as a driver. He's a seasoned pro, and he knows what he needs in his race cars."

Chris, Denny, and the team fought through numerous challenges, including a series of devastating crashes that eliminated more than half of the field. After more than 500 grueling miles, Denny Hamlin's #11 FedEx Toyota Camry crossed the finish line in first place, in Chris' first ever race as crew chief. "We were very fortunate," recalls Chris. "I have very fond memories from that race. But really, it was a team effort. It was all about Denny Hamlin and Joe Gibbs Racing that weekend."

As monumental as that win was, Chris prefers to talk about the team's next win at Texas Motor Speedway, because of the challenges they had to overcome. "We had a fast car that week," says Chris. "But we had a speeding penalty on pit road, which sent us to the back of the pack. And then after Denny had fought back to the front, NASCAR cited us for having an uncontrolled tire just over the line of our pit box, so we had to go to the back again."

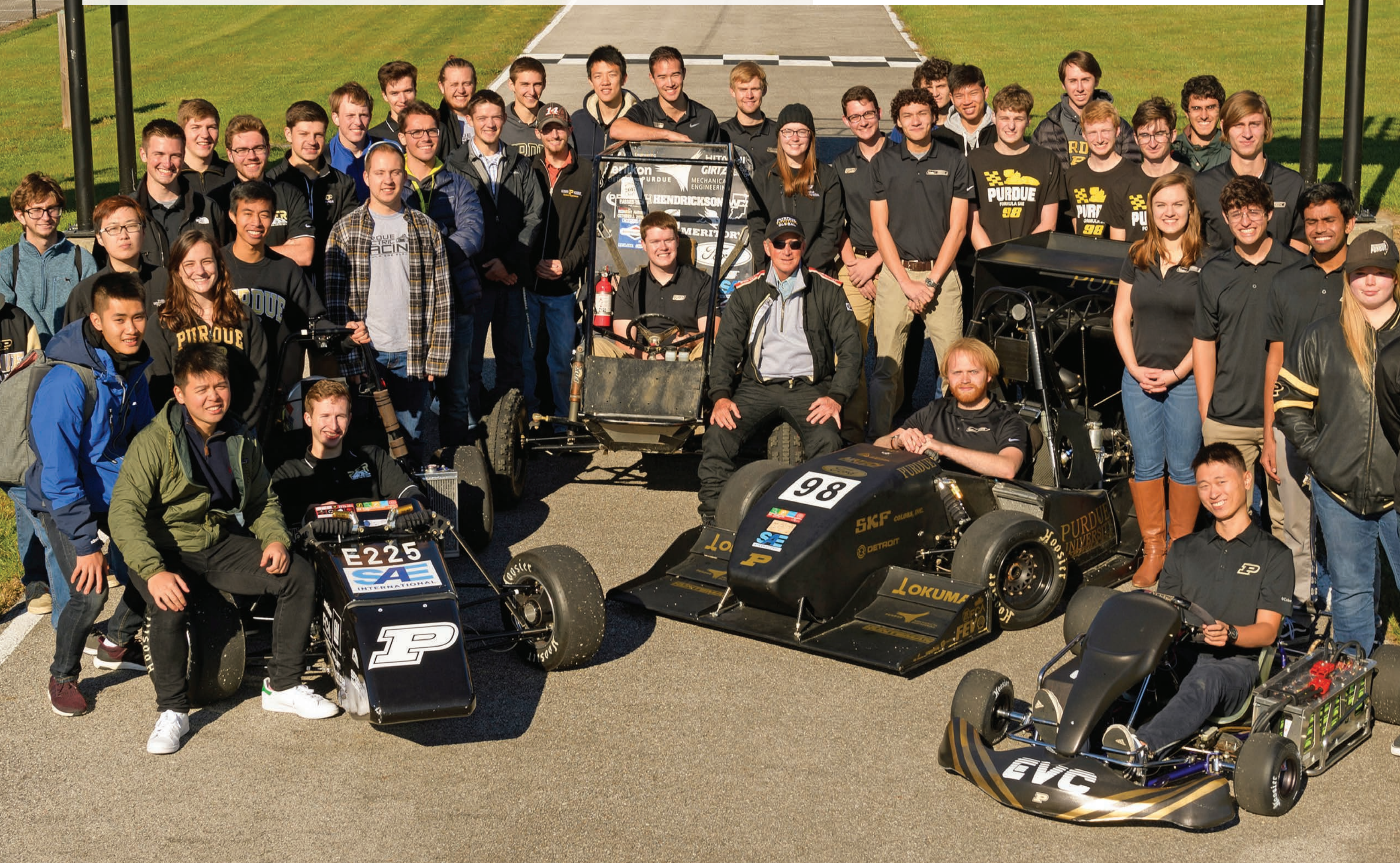
Setbacks like this have the potential to ruin a team's day, and crew chiefs often have to moonlight as psychologists. "Think about the driver of that car," says Chris. "It's 120 degrees in that little cocoon, and he can't turn his head to see what's going on around him. He's working his tail off driving, so we have to keep him motivated. The pit crew is upset with themselves because they made a mistake, so we have to assure them that it's not about perfection, but about overcoming the obstacles and doing everything to the best of your ability."

The team rallied in Texas, and after some gutsy calls and heroic driving, the #11 car once again took the checkered flag in first place. It was the first time since 2014 that a team had overcome two major penalties to win a race. "We have built up a great trust with each other," says Chris. "Whether the situation is good or bad, we always shoot straight with each other. A race like that really highlights what our team is about."

"I hold Purdue in such high regard," reflects Chris. "There's no question that engineering got me into the job I'm in now. They trained me in more ways than I could have realized at the time: the problem-solving skills, the analytics. All of those things were a huge asset to get me where I am today."

NEED FOR SPEED

Every year, Purdue MEs design and build race cars from the ground up, competing against other universities around the world. The **Baja** team builds a single-seat off-road vehicle with massive suspension. The **Formula** team builds an internal-combustion race car which goes from 0 to 60 mph in less than four seconds. And the **Electric** team gives their car instant acceleration from a 300-volt battery. Motorsports is a proud tradition at Purdue, as evidenced by the annual **Purdue Grand Prix**, the spectacle of go-kart racing which has been held on campus since 1958. More recently, Purdue has also created the **EV Grand Prix**, an event for electric go-karts held at the Indianapolis Motor Speedway.



Hot laps with the President

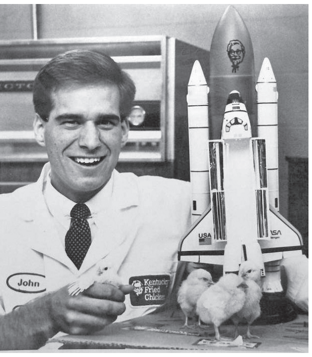
Purdue President Mitch Daniels recently had the opportunity to test-drive the Formula Electric car at Purdue's Grand Prix Track. "These electric cars have instant acceleration," said Daniels, well known for driving sports cars. "But it's different, because these make so little noise. They get around pretty quick!" Daniels added, "This is all student-built equipment, student-run teams. It's so impressive. I'm thrilled and inspired by Purdue Engineering in all its forms, and this is just a great example among many."

WHAT CAN YOU DO W

Alumni achievements show Mechanical Engineering's versatility

X-ray mice in space

As a student in the 1980s, **John Vellinger** (BSME '89) won a nationwide contest to send an experiment aboard the Space Shuttle, determining how chicken eggs would develop in a low-gravity environment. He even teamed up with Kentucky Fried Chicken to brand the experiment "Chix in Space"! That may have been the highlight of many students' careers, but John was just getting started. With his Purdue engineering experience, and KFC's marketing know-how, he saw an opportunity to create more experiment modules for NASA.



"And that's all I've been doing for the past 30 years!" jokes John, now founder and CEO of Techshot Inc., a company that builds experiment modules for the International Space Station. Within the extremely rigid size and regulatory requirements from NASA, Techshot have been able to design, build, and launch some incredible pieces of equipment: a centrifuge with variable levels of gravity that can simulate the Moon or Mars; an x-ray bone densitometer for mice, so astronauts can experiment with how to keep their own bones from becoming brittle; and even a 3D printer capable of manufacturing human tissues in microgravity.

John says it all wouldn't have been possible without his degree from Purdue ME. "You can have good ideas," he says, "but the implementation of those ideas requires you to drill down into the details. And that's what Purdue taught me. They gave me the building blocks to be a solid engineer, but they also helped me become a strong businessman. They taught me the processes and procedures to take those ideas and turn them into reality."

Build a foundation for others

Anthony "Tony" Harris (BSME '75) has always loved math. But he didn't take calculus or any advanced classes in related fields; they weren't even available at his southside Chicago high school in the 1960s. But that never stopped him from dreaming big. "I was a pretty cocky kid," says Harris, now president and CEO of Campbell/Harris Security Equipment Company. "I didn't think anyone could outperform me in math, no matter what prerequisites they'd taken. Looking back, sometimes it's good when you don't know how steep the mountain is that you're about to climb."

Harris would come to be passionate about helping others climb that mountain. At Purdue, he helped to found the National Society of Black Engineers (NSBE), now the largest student-run organization in the country with 27,000 members and chapters on five continents. "It all started with a little brotherhood of six guys," Harris says. "There's no way we could have imagined what NSBE would become." They invited engineers to come speak at Purdue, they put together a resumé book, and they helped other black students to feel supported and welcome in the engineering major. "We planted a seed, but we get way too much credit," Harris says. "All the students since have run with it and made it what it is."

"The challenges for black students have changed," he says. "It's not about schools not being willing to accept us; it's about preparation. Now we're focusing on getting kids interested as early as third or fourth grade. We need to teach them early that math is fun, relevant, and a great opportunity for them."

WITH AN ME DEGREE?

Serve 14 million beverages a day

Ask **John Biasi** (MSME '87) "So, what do you do?" And there is no simple answer. The lights on the Empire State Building. The Coca-Cola Freestyle Machine. Robotic arms for amputees.

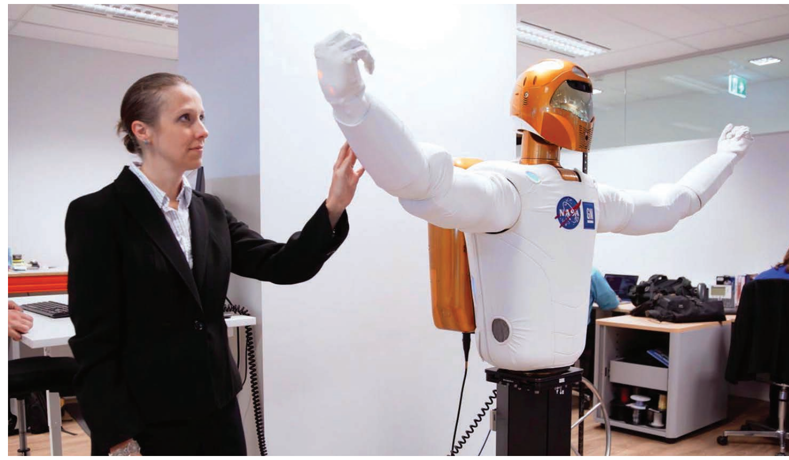
But it all started at Purdue. "Professor Galen King was a great mentor to me," says John, who focused on controls and mechatronics. "So I had a master's degree in mechanical engineering, and in my first job I ended up... writing software!"

This job, programming robots to paint cars at a Ford factory, led to several roles in controls software for manufacturing, and eventually into marketing, strategy, and mergers & acquisitions. Then he joined a company called Color Kinetics (soon acquired by Philips), which produced large solid-state lighting for venues like Disney theme parks and the Empire State Building.

Then Dean Kamen came calling. "I didn't know Dean Kamen at first," recalls John, "I knew about the Segway, and about his founding of FIRST Robotics. But he told me what he needed my help with was the Coca-Cola Freestyle Machine." Dean's company, DEKA Research, was attempting to roll out this brand new touchscreen soda dispenser in time for the 2012 London Olympics. Thanks to John and his team, there are now more than 50,000 Coca-Cola Freestyle machines all over the world, pouring 14 million drinks every day.

In addition to the well-known Segway transporter, DEKA focuses on health and mobility technologies, including the iBOT wheelchair (which can raise up and balance on two wheels), and the Luke Arm, a nerve-controlled robotic prosthetic arm.

"Engineering is about solving problems," says John, "and at Purdue, you get the fundamentals of learning how to do that. It's pretty fulfilling when you design something, it works, and people benefit from it. Even if it's just a part or a subsystem, every time someone likes it, that's a really cool feeling."



Program robotic astronauts

"I was the first technical person in my family," says **Julia Badger** (BSME '03). "I just loved solving problems. Then in 9th grade, I read the book *I, Robot*, and I decided that space robots would be where I'd go with my career!"

Purdue ME turned out to be the perfect choice. "Mechanical Engineers can do anything," says Julia. "They know a little bit about electrical things, they work with materials, they do some civil engineering. They touch a little bit of everything. That's why I chose it."

NASA soon entered the picture, thanks to Purdue's co-op program, which allows students to alternate semesters between studying at Purdue and working in industry. "Co-ops are so important, and NASA was my first choice," says Julia. "I interviewed and got in, which was thrilling!"

Soon she joined the team behind the most ambitious robotics project at NASA: Robonaut. "Robonaut is a humanoid dexterous robot," says Julia. "It's designed to function like humans, and share the same space as humans, doing mundane tasks that astronauts would otherwise have to do. Things break all the time, and Robonaut is essentially the repairman." After launching to the International Space Station, Robonaut became a celebrity, even having its own social media following.

Julia's current focus is working on robotics for the Lunar Gateway, a new space station which will only be occupied by humans a few weeks a year – which means robots will be doing most of the work. "We imagine robots on the Gateway doing experiments to test whether humans can survive and adapt to certain environments," she says. "There's a lot of secrets that we haven't unlocked on the Moon and Mars, and robots can help us accomplish that."

"My number one favorite thing about Purdue is how practical they are about solving real-world problems," she says. "Purdue's focus on finding practical solutions is something that serves its graduates well, especially in the space program. Problems are all around us, and engineers are the ones that fix them!"

TOY FAIR

Engineering at play

Remember when your parents told you to "share your toys" with others? Purdue ME students have done just that: sharing their toys with the public, as part of an annual Toy Fair event. In the ME444 "Computer-Aided Design" course, students learn concept generation, CAD design, finite element analysis, and rapid prototyping, and other skills necessary to work in industry. But all their hands-on learning takes place with toys, and their final project involves designing and building a new action toy.

Testing out a prototype arcade game

Why toys? "Toys are the perfect metaphor for simulating the types of projects that engineers work on in the real world," says professor Karthik Ramani, who started the class in 1997. "Everyone played with toys when they were little, so they all know about the experience. But in this class, they learn how engineers and designers conceptualize and create those toys."

"You could cover product design in the classroom," says continuing lecturer Min Liu, who now teaches the class. "But our very first class is actually a lab. We want students to get hands-on as soon as possible, and toy design is a scaffolding that helps them learn the design process holistically. We call it the i6 framework: inspiration - ideation - imagination - iteration - implementation - innovation."

As part of their final project, students team up to develop a brand-new toy, create a working prototype, and present it to a panel of judges at the annual Toy Fair. Through the years, students have created an incredible variety of toy concepts, from a remote-control chicken and autonomous octopus, to marble mazes and hydraulic cranes. Some are built around high-tech micro-controllers and sensors, while others are simple puppets or board games that don't even require batteries. The Mechanical Engineering building even hosts a Toy Museum, where dozens of these eclectic prototypes are on display. "We are very lucky to have this museum space," says Ramani. "Every one of these toys has the potential to become an amazing product."

Karthik Ramani

This train can be remotely controlled from your phone

See more toys at purdue.edu/ME/toys

Purdue ME's Toy Museum

SENIOR DESIGN

Industry has big demand for student innovations

These students developed a packaging solution for Proctor & Gamble

Finishing the Purdue ME degree is a difficult climb. But the final class in your senior year could also be your greatest opportunity.

ME463, or Senior Design, teams up students with faculty members and industry partners to create prototype products, continually refining and improving them using the knowledge from their engineering courses over the last four years. At the end of the semester, the students present their final prototypes to a panel of Purdue ME alumni judges.

"It's definitely a pressure cooker," says professor Greg Jensen, director of senior design. "Since they only have one semester, students begin working the first week on understanding the problem to be solved, who has the problem, why it is a problem and what others have done to solve the problem. They proceed through creation of solutions, analysis that predicts behavior and sizing components, purchasing, fabrication and assembly, and then testing – all in 15 weeks. It is a very aggressive process."

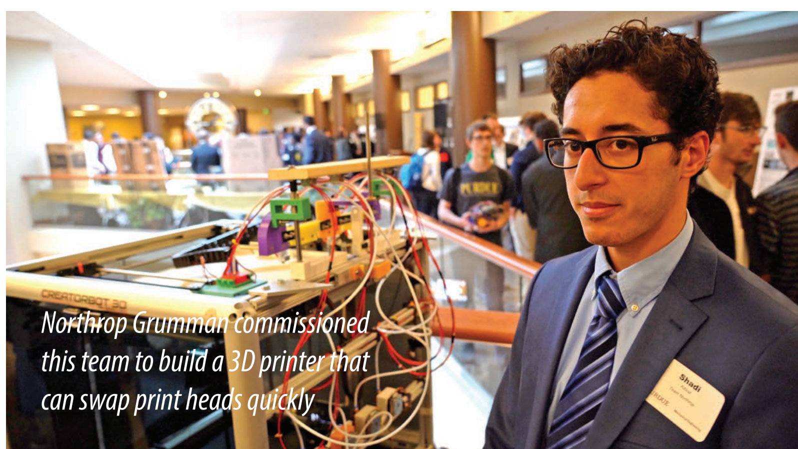
The prototype ideas can be created from scratch, but recently, student groups have received engineering challenges from Purdue's many industry partners – for example, fixing an issue in their manufacturing process, or refining an installation of their product. "It really mirrors what engineers do in the real world," says Jensen. "Some of them are creating new products, but many are just refining processes that already exist, to make them better. Our students have worked with local manufacturers, all the way up to big companies like Rolls Royce, Fiat Chrysler, and Boeing."

Student teams work closely with industry representatives

At the end of the semester, the teams of students compete for the Malott Innovation Awards. Created in 2007 by Thomas J. Malott (BSME '62), former president and CEO of Siemens Energy and Automation, the awards are designed to foster an innovation culture at Purdue ME. Students present their prototypes to a panel of industry judges, who select winners to receive cash prizes for innovation and engineering excellence. The day ends with all 50+ teams showcasing their final projects in a public open house, attended by many of the industry representatives.

"What's great about these projects is that they aren't just makework," says Jensen. "Our industry partners are looking to Purdue ME students for real solutions, and they are amazed by what our teams come up with. We've seen numerous examples of innovations created as part of the class, which are now being implemented in facilities around the world. And it's a great stepping stone to employment for many of our graduating seniors."

Using 3D scanning and printing, this team designed custom shoe inserts for partial amputees



Northrop Grumman commissioned this team to build a 3D printer that can swap print heads quickly

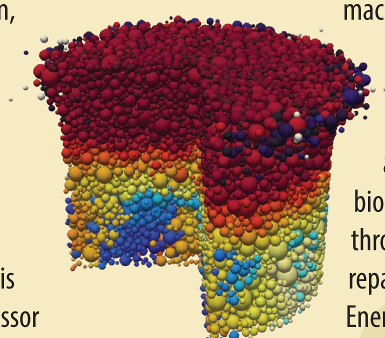
PARTICLE PEOPLE

No one studies particles like Purdue

Powders and particles are everywhere – from the food we eat, to our laundry detergent, to the pharmaceutical tablets we take. But they can also be a great mystery.

"We have a pretty good understanding of solids, liquids, and gases," says professor Carl Wassgren. "But particles are different. Sometimes they flow like liquids, and sometimes they behave like solids. They can be all different sizes, shapes, and consistencies. We don't really have good models for predicting the behavior of these materials during manufacturing."

That's why Purdue created the Center for Particulate Products and Processes (CP3), a preeminent team led by Wassgren, including members from mechanical engineering, chemical engineering, materials engineering, agriculture, food science, and pharmacy. Their goal is to establish the science behind powders and particles which make up a trillion-dollar market for pharmaceuticals, foodstuffs, and more.



Take tablet manufacturing, for example. "This is an incredibly complex industry," says assistant professor Marcial Gonzalez. "Pharmaceutical companies are highly regulated, but they also have to be on the cutting edge of manufacturing processes." Purdue's solution? Build a complete pharmaceutical manufacturing plant, right on campus. "This is the complete downstream manufacturing of pharmaceutical tablets," said Gonzalez. "We start with powders that we mix together at a specific ratio, which get compacted into a continuous ribbon and milled into granules. The granules are then lubricated and fed to a tablet press, which creates thousands of tablets an hour. At every step, we have a variety of sensors that measure the quality and consistency of the product and the process."

This facility is the centerpiece of a new \$3.95 million grant from the Food and Drug Administration (FDA). "We're one of only two schools in the country that have anything like this," adds Gonzalez.

Such high-level research demands high-level diagnostic tools. CP3 recently moved its Particle, Powder, and Compact Characterization Lab into the new Flex Lab building. "Everything needed to test particles is here," says Wassgren. "We can test particle size, shape, density, flow characteristics, and more. We even have a micro-CT machine that allows us to look at the internal structures of very small materials without breaking them apart."

This comes in handy when examining something like biomass (agricultural by-products like corn stover and soybean hulls). In refineries that make ethanol, this biomass often accumulates and compacts while moving through augers, forcing costly shutdowns for cleaning and repairs. The Department of Energy recently turned to Purdue with a \$1.8 million grant to solve this problem. "We can create models to predict the physical properties of the biomass," says Wassgren, "and what is necessary to make it flow more like a liquid. This involves adjusting the consistency of the biomass, as well as adjusting the equipment to operate efficiently."

So the next time you eat corn, drive a hybrid car, take a pharmaceutical tablet, or powder your nose, be sure to thank Purdue and its particle people!

ENERGY CORRIDOR

The US-Mexico border is a once-in-a-lifetime opportunity

When you think about the US-Mexico border, it's easy to become discouraged focusing on politics, immigration, and humanitarian issues. But professor Luciano Castillo sees this as a once-in-a-lifetime opportunity for engineering to provide the answer to all these problems. "Instead of a wall, we should build an energy corridor," he proposes. "Renewable energy has the potential to solve so many issues for people in both the United States and Mexico."

Castillo leads a coalition of 28 engineers and scientists from across the country who have proposed an audacious plan: convert all 2,000 miles of the US-Mexico border into a renewable energy park. With solar panels, windmills, natural gas pipelines, and desalinization, an energy corridor would convert one of the most contentious areas on earth into one of the most stable and beneficial areas for both Americans and Mexicans.

Let's start with the basics: the American southwest is rich with potential for renewable energy. The solar energy output could equal that of Niagara Falls. The wind energy of Baja California and the Texas Gulf Coast are ideal. New Mexico and Texas also hold major natural gas reserves.

But to Castillo, these are just preliminary to the main issue in the Southwest: water. "That area is always prone to droughts," Castillo says. "Conservation efforts are laudable, but as the population increases, it won't be enough to bring that area out of its crisis."

An energy corridor solves the water problem in two ways. First, according to Castillo's research, more than half of the fresh water in the US is used to cool fossil fuel and nuclear power plants. By replacing them with renewable energy, that water becomes available for other uses. Second, renewable energy will power desalinization plants at both coasts, bringing water pipelines into the desert for new agriculture, industry, and domestic use. Economic development would follow in turn, as people flock to the steady employment of these new industries.

The plan has its challenges, including border security, environmental issues, and the economic and political will to engage in such a huge project. But for Castillo, it's good to think big. "The transcontinental railroad transformed the US in the 19th century," he says. "The Interstate Highway System transformed the US in the 20th century. This is the vital infrastructure endeavor of the 21st century."

More importantly, it's an effort based entirely on sound science, rather than partisan ideology. "This is a different kind of initiative that will solve many existing challenges while bringing people together," Castillo says. "It will bring energy, water and education to create more opportunities for the US and Mexico on both sides."

Psychrometric chambers keep it cool

"Buildings use 40% of the country's electricity," says Orkan Kurtulus, a research engineer at Herrick Labs, the largest academic HVAC lab in the world. "So testing this equipment is crucial to saving energy, and still ensuring that end users have comfortable homes and offices." Testing HVAC equipment (heating, ventilation, and air conditioning) requires a psychrometric chamber, a custom-built room that can create consistent conditions of temperature, humidity, pressure, and airflow. Herrick Labs operates six of these chambers.

The chambers function in pairs: an 'outdoor' chamber that simulates the compressor and heat exchanger sitting outside the home, and an 'indoor' chamber that duplicates the room-temperature environment inside the home. "This way," says Kurtulus, "we can re-create summer conditions to observe air conditioning equipment, or winter conditions to test which heating method is most efficient."

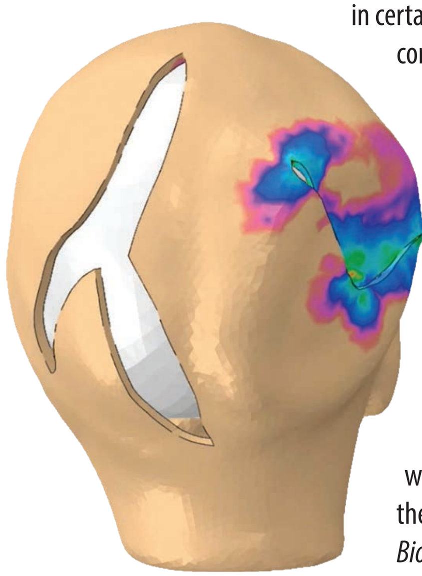
The chambers are incredibly precise. They can maintain a constant environment within 0.5° C of their intended target, and 1% of their humidity target. They can also duplicate extreme conditions, from -20° C (-4° F) to 55° C (130° F), and from 15% to 100% humidity. That consistency is important, because researchers aren't just monitoring the temperature of the air, but the refrigerants used to cool the air. "Refrigerant research is very important," says Kurtulus. "We're all working to find a refrigerant that is friendlier to the environment, but still efficient enough to do the job."

Herrick Labs has been investigating air-conditioning and refrigeration since 1958. "When it comes to thermal systems, Purdue is leading this research," says Kurtulus. "Not just in the US, but worldwide."

"Virtual surgery" for wound healing

Human skin, like any other material, obeys the laws of physics – which means its mechanics can be predicted in computer simulations. Now a Purdue team are bringing this technology to reconstructive surgeries. Using smartphone photos and computer analysis, surgeons can now predict how specific wounds and scars will heal.

Assistant professor Adrian Buganza discovered that surgeons largely function by intuition and "feel" when assessing the skin of a patient. "They have an inherent understanding of the mechanics," said Buganza. "They know that stretching the skin in certain places will likely introduce complications in the healing process. But I was surprised to learn that there are no tools available to them to measure this tension, and give them quantifiable options." Buganza and his team created a new methodology to predict how skin will heal, and verified the process in a real-world surgical case, publishing their results in the *Journal of Biomechanics*.

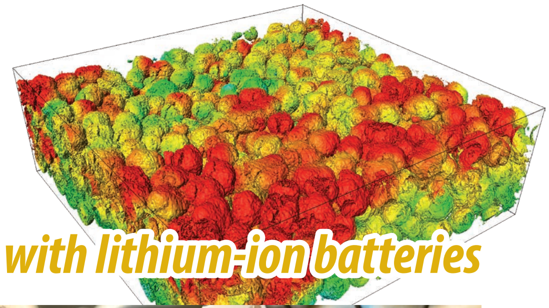


Using simple smartphone photos from different angles, they were able to create a sufficiently accurate computer model of a wound. Step two involved testing the elasticity of the skin, using a small suction device. "Once the computer has those two elements – the geometry and the skin's mechanical properties – then we can build the computer simulation using finite element analysis," says Buganza.

Before the surgeon ever makes an incision, the software can perform "virtual surgery" – showing the most likely outcome of the healing process, and indicating where complications are likely to occur. Based on the data, the surgeon may choose to cut in a different way, in order to minimize the potential healing problems.

"The best part about virtual surgery is that we can do it many times," said Buganza. "It's not just one shot. We can give the surgeon many different options, and offer statistical probabilities of which option will be best for the patient. This kind of personalized medicine – using computational models to predict tissue behavior of each patient – has the potential to completely change the way these procedures are performed."

HIGHLIGHTS



Giving machines "spidey senses"

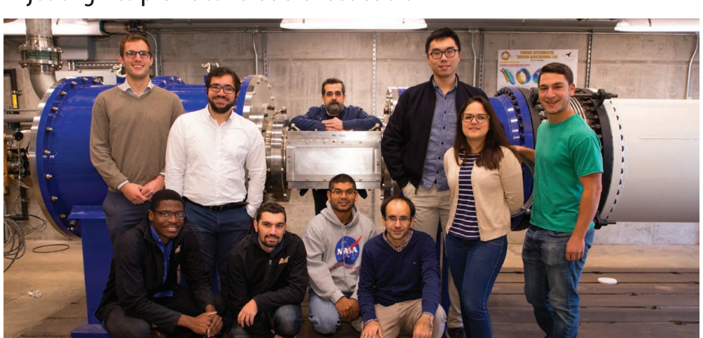
What if drones and self-driving cars had the tingling "spidey senses" of Spider-Man? They might actually detect and avoid objects better, says assistant professor Andres Arrieta. "Current sensor technology doesn't process data fast enough – but nature does!" says Arrieta. Spiders, bats, birds and other animals have nerve endings linked to special neurons called mechanoreceptors, which only detect and process information essential to an animal's survival. "Nature doesn't have to collect every piece of data," he says. "It filters out what it needs."

Nature is also able to instantaneously act on that data, without needing a power supply. Purdue researchers, in collaboration with Nanyang Technology University in Singapore and ETH Zürich, have designed sensors that do the same, using the on/off states of these mechanosensors to interpret signals. The idea would be to integrate similar sensors straight into the shell of an autonomous machine, such as an airplane wing or the body of a car, enabling it to react instantly to threats, with no delays or extra processing. "With the help of machine learning algorithms, we could train these sensors to function autonomously with minimum energy consumption," Arrieta says.

Through the fire and flames

Put a normal temperature sensor in a rocket flame or a jet engine, and it will melt. So how do you measure temperatures and pressures at these extremes? Invent your own sensor!

Guillermo Paniagua researches turbine aerodynamics at Zucrow Labs, the world's largest academic propulsion lab. His team had trouble finding a commercially available sensor that could withstand the extreme environments of a jet engine. So they used their experience in computational fluid dynamics to design a tiny probe that functions in 1,300° F; and they're working on a prototype that can survive twice that. "This work is crucial," says Paniagua. "In the aerospace industry alone, even a 0.5% improvement in engine efficiency would lead to $2 billion a year in fuel savings. So putting a small, unobtrusive device in jet engines provides valuable feedback."



Get closeup with lithium-ion batteries

Our lives run on lithium-ion batteries: from smartphones and laptops, to electric vehicles like cars and buses. And yet we still don't know the fundamentals of how they work, and why they degrade so quickly. "Most people think a battery is an electrochemical system," says assistant professor Kejie Zhao. "But actually, it's a mechanical system – parts that move, and deform, and degrade. These parts just happen to be very small."

Zhao is part of a team that has developed the most comprehensive view yet of lithium-ion electrodes. Using micro CT and X-ray tools, they have successfully imaged the electrode at the millimeter level, the micron level, and even down to individual atoms, using machine-learning algorithms. They have found that degradation in battery particles doesn't happen at the same time or in the same location; some particles fail more quickly than others.

"This really fills a gap in fundamental understanding of lithium-ion batteries," says Zhao. "The ultimate goal is to help manufacturers make batteries with better performance, which are also safer and more reliable."

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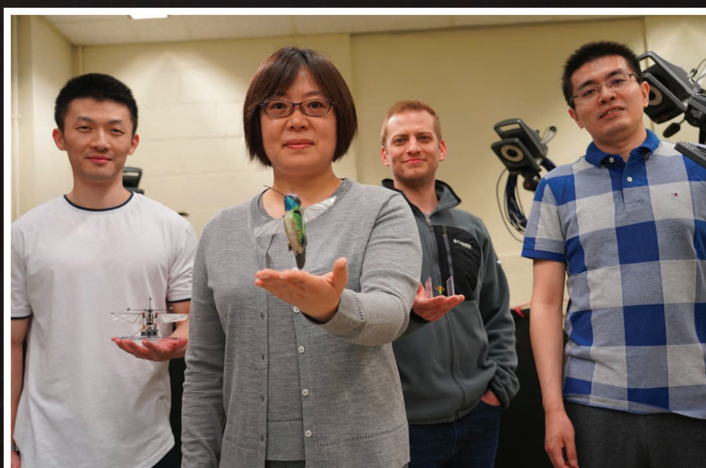
HUMMINGBIRD ROBOTS

What can fly like a bird and hover like an insect? Your friendly neighborhood hummingbird! Professor Xinyan Deng and her team have created a robot inspired by this amazing feat of nature. Weighing just 12 grams, the robot can hover, fly in predetermined paths, execute sharp turns, and even remain stable if its wing becomes damaged.

With no camera or GPS, its flight mechanics are based on artificial intelligence derived from researching actual hummingbirds. And because it utilizes unsteady aerodynamics, a hummingbird-style drone can be much smaller, more resilient, and more maneuverable in windy conditions and confined spaces.



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