

PURDUE
UNIVERSITY®

Mechanical Engineering

THE SKY'S THE LIMIT

Mechanical Engineers and Purdue's place in space



*"Purdue was one of the best
decisions I ever made in my life."
-Astronaut Scott Tingle*



PLUS:
What can
you do with
an ME degree?

purdue.edu/ME



Hello friends,

I've just returned from China, where Purdue ME renewed its 10-year relationship with Shanghai Jiao Tong University. Over the past decade, **more than 300 Purdue ME students have spent semesters in Shanghai**, learning not only about engineering but also about how to be a global citizen. It's a point of pride for me that **45% of Purdue ME students study internationally**, whereas the national average is just 5%.

It got me thinking about the influence of Purdue ME around the world, beyond just our numerous Study Abroad opportunities. Our 19,000 alumni are having a positive impact in every corner of the globe, whether in industry, education, or their communities. Anywhere I travel, I meet amazing people who chose to spend their formative years in West Lafayette.

And as you'll read in this magazine, **that influence even reaches above the earth!**

Purdue MEs play a huge role in modern space exploration as astronauts, rocket scientists, biomedical engineers, entrepreneurs, and more.

Just as Purdue's original 19th century "Boilermakers" were the foundation for the locomotive age, this 21st century golden age of space exploration unfolds with Boilermakers at the controls.

It's a great time to become a mechanical engineer! And Purdue is a great place to make it happen!

Anil Bajaj

Anil Bajaj

William E. and Florence E. Perry Head & Alpha P. Jamison Professor of Mechanical Engineering



Learn about Shanghai, and all Global Engineering Programs, at:
engineering.purdue.edu/GEP



**Purdue University
School of Mechanical Engineering**

585 Purdue Mall
West Lafayette, IN 47907
Phone: (765) 494-6900
Fax: (765) 494-0539

Website: purdue.edu/ME



*This magazine was produced by Jared Pike (jaredpike@purdue.edu),
Communications Specialist, School of Mechanical Engineering.*

*Photos courtesy of NASA, Purdue University, Purdue Research Foundation,
Shanghai Jiao Tong University, Trevor Mahlmann, Scaled Composites,
Vanderbilt University, Georgia Institute of Technology, Moira Gunn, Ken
Morris, IntuiTap Medical, Purdue Baja SAE, Purdue Formula SAE, Purdue
Electric Racing, Purdue Hyperloop, Westside Boiler Invasion, and ETH Zurich.*

PURDUE
UNIVERSITY

Mechanical Engineering

Our Place in Space..... 4-7



*From astronauts to engineers, Purdue MEs are at
the leading edge of modern space exploration*

What Can You Do With an ME Degree? ... 8-9



Just about anything!

We Love to Compete 10-13



*Engineers aren't all about theory -- we also like to
build race cars and robots!*

Research Highlights 14-17



*Purdue ME research includes energy storage,
biomedicine, fluid mechanics, and so much more*

World-Class Facilities 18-19

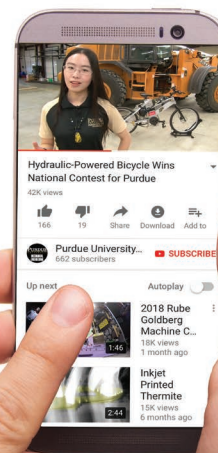


*Purdue hosts some of the finest research facilities
on the planet*

THIS MAGAZINE IS INTERACTIVE!



*Watch videos of every story, and get bonus content at:
purdue.edu/ME/magazine*



OUR PLACE

Scott Tingle is the latest in a long line of Purdue engineers to



Perhaps you've seen that American flag planted on the Moon. Purdue grad Neil Armstrong took those first "giant leaps" in 1969.

But Purdue's place in space isn't just in history books. Today's Purdue engineers are involved in every aspect of spaceflight, from designing rockets and satellites, to sustaining future astronauts.

Scott Tingle (MSME '88) is a perfect example. He enlisted in the Navy as an aviation ordnanceman, but his dream was to fly in space. He knew a graduate degree would help him achieve that goal, and as the "Cradle of Astronauts," Purdue was the place to get it. "I used to do my homework in the basement of the Mechanical Engineering building," Scott remembers. "All my friends were down there doing flow measurements with lasers. It was a geeky place; I just loved it!"

His Purdue connections helped him get his first engineering job at



Spacewalk training at NASA's Neutral Buoyancy Lab

the Aerospace Corporation in California, where he worked with spacecraft propulsion. He then became a naval aviator, compiling more than 4,500 flight hours on 51 types of aircraft, 750 carrier arrestments, and 54 combat missions. Finally, on his fourth application in 2009, Scott was accepted into the NASA Astronaut Corps.

It wasn't until Scott joined NASA that he fully realized how many Purdue grads are in the space program. He jokes, "You can't

swing a dead cat around here without hitting a Boilermaker!"

In fact, Scott shared his first mission to the International Space Station with another Purdue grad, Drew Feustel. During Expedition 55, they grew vegetables in zero-gravity, conducted human physiology experiments, and went on a 7-hour spacewalk to upgrade the station's

THE RIGHT STUFF

Of the 24 Purdue grads who have become astronauts, four are Mechanical Engineers

One of the original Mercury Seven, **Virgil "Gus" Grissom** (BSME '50) became just the second American to fly in space. He also helped design the Gemini capsule, and commanded its first mission. He and his crew died in the Apollo 1 accident in 1967.

Jerry Ross (BSME '70, MSME '72) studied thermodynamics at Zucrow Labs. A test engineer for the Air Force, he became a record-setting astronaut, embarking on 7 Shuttle missions and 9 spacewalks.

Donald Williams (BSME '64) flew 330 combat missions in Vietnam, worked as a flight instructor for NASA, and made his own Space Shuttle flights in 1985 and 1989.

After Purdue, **Scott Tingle** (MSME '88) became a naval aviator, with more than 4,500 flight hours. At age 52, he launched on his first spaceflight in 2017.



E IN SPACE

reach for the stars

robotic arm. They even spoke live via satellite at Purdue's commencement ceremony.

Through it all, Scott's training as a mechanical engineer has helped him secure his place in space.

"I've always said that attending Purdue University was the best professional decision I've ever made in my life," he said. "If you go to Purdue, you'll be prepared academically, technically, and practically. We're the kind of people that like to get in there and get up to our elbows in grease. We know how systems go together, and how to work in a team. You can't get that experience everywhere."



Growing vegetables was one of hundreds of scientific experiments Scott performed on the International Space Station.



Boiler up! Dozens of Purdue alums at NASA supported Scott during his mission, including flight director Gary Horlacher, and director of Johnson Space Center, Mark Geyer.

GOOD HANDS

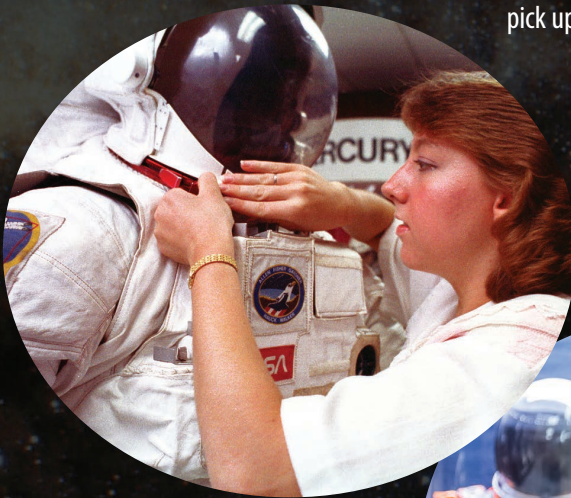
For **Amy Ross** (BSME '94, MSME '96), designing the gloves used by spacewalking astronauts isn't just a passion -- it's the family business!

"My dad was very enthusiastic about his work," says Amy about famous astronaut (and fellow Purdue ME) Jerry Ross. "He's always told me that I need to do something I care about, something that challenges me, and something I enjoy. So I asked him how people work at NASA, and he said that engineering is the degree most people get, and that Purdue has a strong connection to NASA through their co-op program. So it became my mission in life to get into Purdue, become an engineer, and get into the co-op program!"

Cooperative education (or co-op) allows students to alternate semesters between studying at Purdue and working in industry. NASA co-ops are unique, because students can "try out" different divisions over multiple semesters. Amy gravitated (so to speak) toward spacesuit design. Her first big responsibility was to redesign spacesuit gloves, to improve dexterity and comfort. And who would be the first astronaut to test these new gloves in a real-world spacewalk? Her father, Jerry Ross! During the first trial run in 1998, he gave them a literal thumbs-up -- and every astronaut since then has used Amy's gloves on their spacewalks.

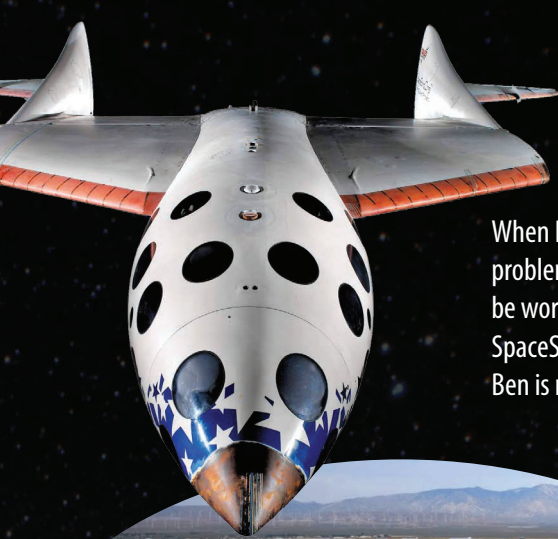
As humans potentially travel to the Moon or Mars, Amy's team is working on the next generation of spacesuit. "If you're doing geology on a planetary surface," says Amy, "you'll need to walk. You'll need to run. You'll need to bend over to pick up rock samples. Our next suit will give you the tools to be able to do that."

"What I like about the job is that it's hands-on," says Amy, pun fully intended. "I come to the lab every day and touch real spacesuits. Some people who work on a rocket engine may see it once, or never see it at all because their work is on a computer. But to be a good spacesuit engineer, you need to physically get into the spacesuit. The human body is a complex system, and that's what makes it so challenging."



As a Purdue student, Amy Ross did a NASA co-op. She loved it so much, she's been there ever since! She's now the head of Advanced Spacesuit Pressure Garment Development for NASA.





GO FOR LAUNCH

When **Ben Diachun** (BSME '99) attended Purdue ME to learn problem-solving, he never imagined his first challenge would be working on the world's first privately-funded spacecraft, SpaceShipOne (left, which now hangs in the Smithsonian).

Ben is now president of the company that built it,

Scaled Composites. His next challenge? The world's largest airplane, the 385-

foot wingspan Stratolaunch,

designed to deliver payloads to multiple orbits and inclinations in a single mission.

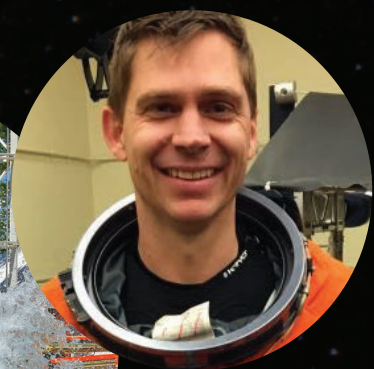
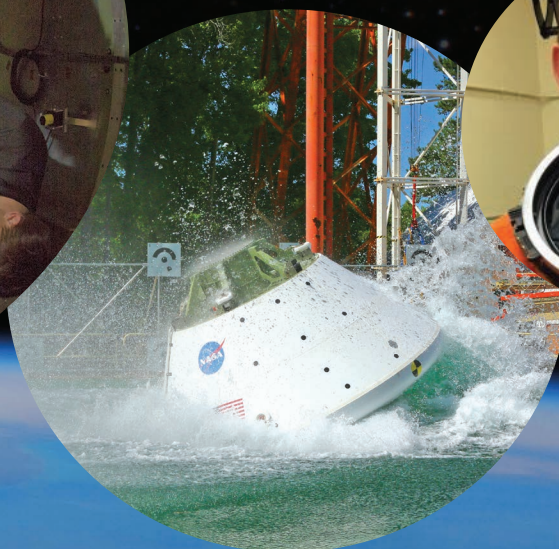
"We're still exploring what is possible in aerospace," says Ben. "We're going to keep going."



ORION'S BELT

As a biomedical engineer at Lockheed Martin, **Mark Baldwin** (BSME '97) is helping to test NASA's next deep-space crew capsule, Orion, for all contingencies of human comfort and safety. For example, during the vibration of liftoff, can astronauts easily read and operate the controls? And during splashdown re-entry, when some of the greatest G-forces occur, how will astronauts be protected?

Mark's real-world torture tests on the ground will lead to safer spaceflight in the stars.



Learn more about Purdue's place in space at purdue.edu/space

WHAT CAN YOU DO W

Host an NPR radio show

"I didn't think I was ever going to go into engineering," says **Moira Gunn** (Ph.D. '74), now the host of the NPR radio program *Tech Nation*. "I came from a family of history and English majors! But even as a kid, I knew I loved math. I would rather do math on a Saturday morning than go to the movies!"

Math-loving Moira found her way to Purdue as a graduate student in computer science in the 1970s. That's when a chance encounter steered her in another direction. "Dick Garrett, who headed the Computer-Aided Design department of Mechanical Engineering, found out about me," she says. "He looked at my transcript, and saw how much math and science I had already taken, and told me that I was only a few credits short of an



The broadest of all engineering disciplines, Mechanical Eng

engineering degree. And he said, 'you already do better work than the guys in my lab!' So that's how I got a Ph.D. in Mechanical Engineering."

After a successful career at traditional institutions like NASA and

IBM, Moira found herself in a very non-traditional role: interviewing scientists at a tiny public radio station in California. "I had read their books," she remembers, "so these astrophysicists and neuroscientists were thrilled that someone was interested in their work." As her PR network grew, scientists would begin to seek her out whenever they had new work to promote. "Then one day I got a call asking if I wanted to interview Linus Pauling. Wow! That's when I knew something was happening here!"

That was the birth of *Tech Nation*, which now broadcasts to millions of people from KQED, the largest public radio station in the country. In each episode, Moira interviews

the most prominent voices in science, technology, business, and biomedicine. "It's really gratifying to see this show become successful," she says. "I've gotten to talk to a lot of people, and hopefully will talk to a whole lot more people in the future!"

Become a triple threat



In his early life, **Baratunde Cola** (Ph.D. '08) combined his love of football with his love of science and engineering. He succeeded at both, becoming the starting fullback at Vanderbilt, and also the first graduate student to work at Purdue's Birck Nanotechnology Center (the largest academic cleanroom in the world). Now a professor at Georgia Tech, he has been recognized with awards from President Obama, and the American Association for the Advancement of Science.

But that's not enough for this triple threat! Baratunde is now also an entrepreneur, harnessing his

expertise with nanotechnology into a startup business: Carbice, which uses carbon nanotubes to build heat-dissipating materials for the space and semiconductor industries.

"I spent a lot of late nights in that cleanroom at Purdue," he says. "A select few people get the opportunity to make something that never existed before. And now it's happening!"



Master the Nürburgring

Talk about a dream job for gearheads! **Ken Morris** (BSME '89) joined General Motors and eventually became the Lead Development Engineer for the original Cadillac CTS. During this time, he pioneered GM North America's usage of Germany's famed Nürburgring racetrack for vehicle development. Morris has driven more than 1,800 laps on the Nürburgring, while leading the dynamic development of GM's vehicles.



WITH AN ME DEGREE?

Engineering at Purdue allows you to do just about anything!

Make spinal taps easier



Lumbar punctures can be difficult and painful -- but a Purdue ME alum wants to change that. **Jessica Traver** (BSME '14, MSME '17) is the CEO of IntuiTap Medical, a startup company launching a device that uses electronic sensors and digital readouts to help guide the procedure.

"I spent about four months rotating in and out of hospitals here in Houston," says Jessica, "And this was the biggest bottleneck we identified. Most doctors do this procedure blindly, by touch. From an engineering standpoint, I knew there had to be a better way."



Jessica's device uses electronic tactile sensors and a digital display to precisely pinpoint the vertebrae -- like a "stud finder" for the spine. Jessica's work with IntuiTap placed her on the *Forbes* "30 Under 30" list of healthcare innovators.

Design for disabled veterans

"There are about 3.9 million veterans with at least one service-related disability in the U.S.," says **Jeffrey Ackerman** (Ph.D. '16). "These disabilities can limit their independence."

Ackerman's company, Prehensile Technologies, has created RoboDesk and RoboTable: devices designed to help people with disabilities use laptops or mobile devices in a wheelchair or bed. They can be finely adjusted to the user's preferences, and then easily retracted without any need for hand or arm dexterity. The devices were developed with a grant from the U.S. Department of Veterans Affairs.

"We want veterans to feel more productive, more entertained and happier while in bed for long periods," says Ackerman. "The more independence we can give to a person with a mobility impairment, the more their quality of life can improve."



Win titles and build Toyotas



It's full circle for **Ukari Figgs** (BSME '99), who grew up working on her family's farm in Georgetown, Kentucky. Excelling at both engineering and athletics, Ukari found Purdue to be the perfect place to pursue both. It paid off big time, as she became the MVP of Purdue's 1999 national champion basketball team, and even won a WNBA title in Los Angeles.

"Because basketball took up so much of my time, I never had an engineering co-op or internship experience," says Ukari. Purdue hooked her up with an internship during the WNBA offseason, which rekindled her love for engineering. Today, she's back where it all started -- in Georgetown, Kentucky, working in production engineering at Toyota Motor Manufacturing of Kentucky.

"For me, every day I come in, I feel like I'm going to help somebody," says Ukari. "Whether it's one of my team members, or a customer who gets the car they need, I'm helping to do that."



WE LOVE TO

Engineering isn't all exams and lab work. Purdue ME students put their sk

Collegiate Drone Racing

Drones have many uses, but it was only a matter of time before college students figured out how to race them at 80 miles an hour!

In this specialized new sport, pilots remotely fly small quadcopters through a course of flags and gates. Cameras mounted on the drones transmit live video to the pilots, who wear video goggles.

The Purdue Drone Club is the largest in the country, with more than 180 members. When founder Tyler Landers (BSME '17) challenged other universities to a series of races, the Collegiate Drone Racing Association was born. Purdue hosts the annual championship event, with 64 of the best collegiate pilots from across the country.

"The racing is fast and furious," says Landers. "Most races only last three minutes, because the battery discharges so fast. And crashes are common, so you've got to be quick on the soldering iron!"

80 mph
OMG!



Watch a first-person view of drones racing at 80 mph!
purdue.edu/ME/magazine

PURDUE
UNIVERSITY

DO COMPETE

skills into practice by participating in competitions -- and have fun doing it!



Purdue's electric car races through the course, powered by a 300 volt battery

Auto Racing

Every year, dozens of Purdue ME students embark on a year-long journey to design a race car from scratch, build it, test it, and then race it against other universities at events sponsored by SAE (Society of Automotive Engineers). There are teams for Baja off-roaders, mini Formula-style racers, and even electric cars. Not only do team members manufacture the car; they are also judged by their business plans, their design and budgeting skills, and their teamwork. It's a great stepping stone into industry -- one student said, "I got three different internships just because of my Baja experience!"

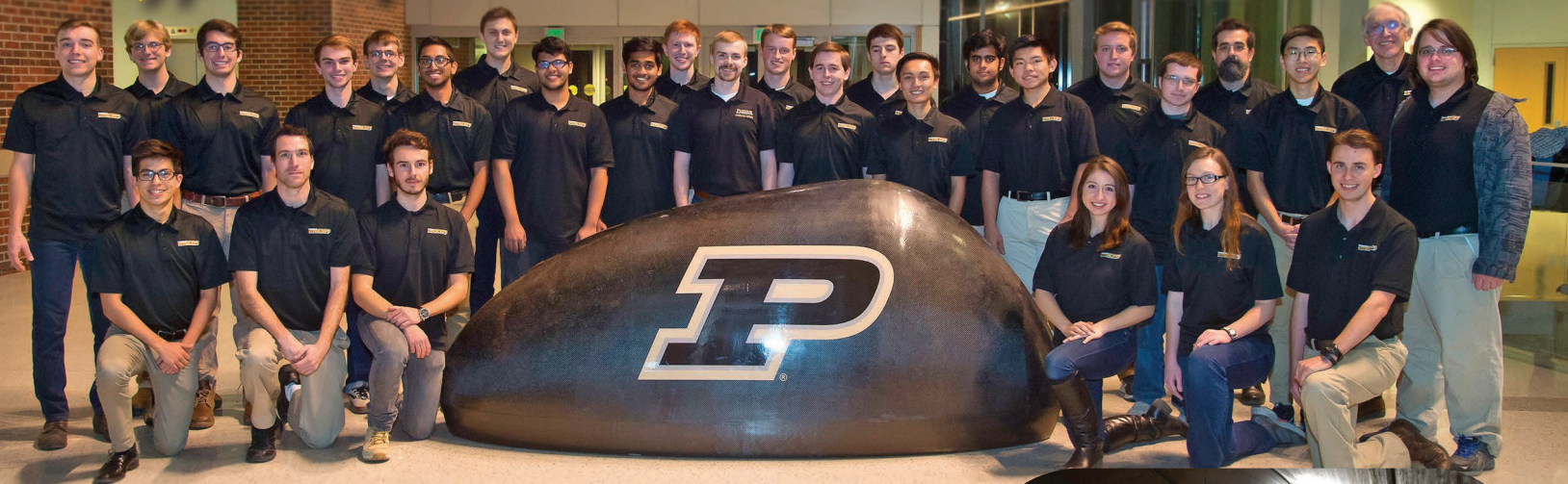


Formula team at the finish line of Michigan International Speedway



Baja car leaps into action in California

Hyperloop



It almost sounds like magic: levitate a pod in a near-vacuum tube, and accelerate to the speed of sound. But Elon Musk's proposed transportation system is very real, and Purdue's prototypes have been there since the very beginning. Purdue students have designed and built several Hyperloop pods for design competitions, including this all-carbon-fiber iteration that ran in SpaceX's test track in California. "This may be the future of transportation," said Guillermo Paniagua, Purdue Hyperloop's faculty advisor. "But there's still a lot to figure out. It's a great problem for Purdue engineers to solve."



Testing at SpaceX

Rube Goldberg® Machine Contest

Building complicated machines to accomplish a simple task is a Purdue tradition, dating back to the 1950s. Other schools joined in the fun, and today thousands of students around the world take part in the Rube Goldberg® Machine Contest. It's the perfect way to integrate everything you learn in engineering, while also showcasing your sense of humor in storytelling! It's no surprise that Purdue ME teams are frequent champions.



You've got to see this machine in motion!
Watch video of the Rube Goldberg® winners:
purdue.edu/ME/magazine

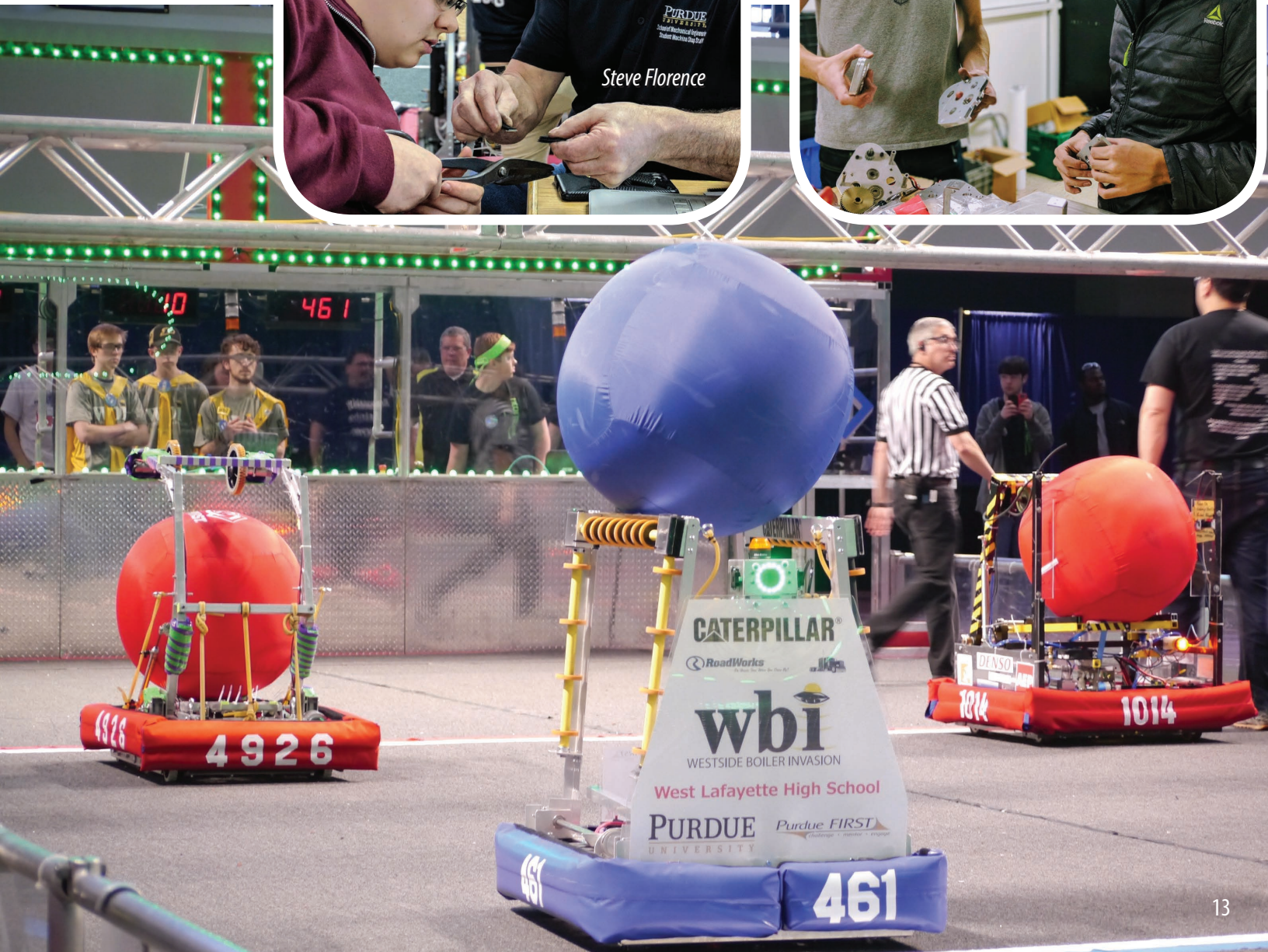


FIRST® Robotics

What's better than competing with your engineering skills? Sharing those skills with others! That's the idea behind Purdue FIRST®, a student group dedicated to mentoring high school robotics teams (FIRST® is a worldwide robotics competition founded by Dean Kamen). Purdue students teach problem-solving skills, assist high school students in building their robots, and then coach them at FIRST® events. "It's all about how we can give back to the local community," says Steve Florence, the group's advisor. "They volunteer their time, but they also learn valuable leadership skills, and receive class credit." Many Purdue ME students are FIRST® alumni themselves; one student said, "If I can inspire students in the way that FIRST® inspired me, then I've done a good thing!"



Steve Florence

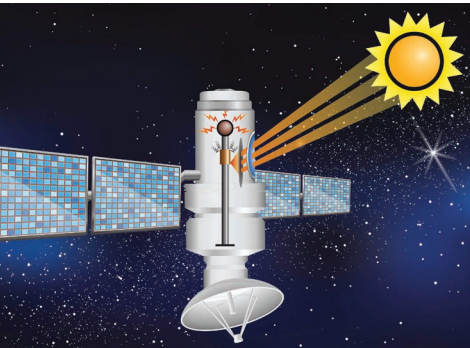


RESEARCH

ACOUSTICS

Thermoacoustics discovered in solids

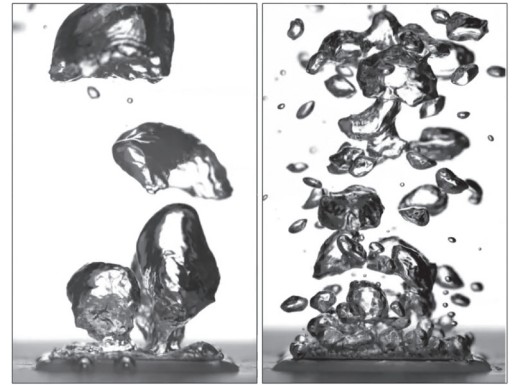
Thermoacoustics is a well-studied phenomenon in fluids, where applying heat to a fluid enclosed in a duct or cavity will cause the spontaneous generation of sound waves. But a Purdue ME team including Fabio Semperlotti has demonstrated for the first time that thermoacoustics could theoretically occur in solids as well as fluids. This could lead to solid state thermoacoustic engines, where extreme temperature gradients could be harnessed to generate motion or electricity, potentially powering future satellites or spacecraft. The team presented their findings at the 175th Meeting of the Acoustical Society of America.



HEAT TRANSFER

Boiling on hydrophobic surfaces

Superhydrophobic surfaces, by their nature, do not seem ideal for removing heat by boiling. But a Purdue ME team led by Justin Weibel has demonstrated that these water-repellent surfaces can support efficient boiling, if all air and vapor is removed from the system first. Not only does this allow efficient boiling, but it stays cooler than its hydrophilic counterpart. This could greatly enhance the cooling of nuclear reactors and high-power electronics. Their research was featured on the cover of *Physical Review Letters*.



DESIGN

EEGs measure human-machine trust

Humans increasingly rely on intelligent machines, such as self-driving cars, or automated factory robots -- which means that we need to trust them. But can that trust be confirmed, or even quantified? At Purdue ME, professors Neera Jain and Tahira Reid have developed a new classification model to measure how well humans trust machines, based on brain-wave patterns and galvanic skin response. It is the first time EEG measurements have been used to gauge trust in real time. The long-term goal is to design intelligent machines capable of changing their behavior to enhance human trust in them. "We are interested in using feedback-control principles to design machines that are capable of responding to changes in human trust level, in real time," Jain said. "This allows us to build and manage trust in the human-machine relationship."



MANUFACTURING & MATERIALS

Soft sensor: anything can be a controller



A new type of tactile sensor can be easily embedded into fabrics, potentially enabling anything in the real world to become an interactive device. iSoft uses multimodal sensing on piezoresistive elastomer, which can then be customized by the user to form any shape or function. For example, clothing could be embedded with video game controls, or a piece of furniture can control your music player. The technology, developed at Purdue ME by professor Karthik Ramani's C Design Lab, can be manufactured on a T-shirt press for less than \$4. "The novel part of iSoft is that it does not need any wiring or electronics within the material," said Ramani. "Even if you have no professional knowledge of electronics, you can modify and customize any object with these soft sensors."

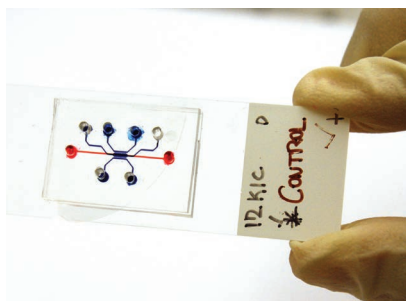
HIGHLIGHTS

NANOTECHNOLOGY 🔍

Tumor micro-environment on a chip

Purdue ME professor Bumsoo Han has developed a nano-scale device that simulates cancerous tumors, allowing doctors to test the effectiveness of precision chemotherapy drugs. The device, about 4.5 centimeters square, contains microfluidic channels where biopsied human cancer cells can be cultured within an extracellular matrix.

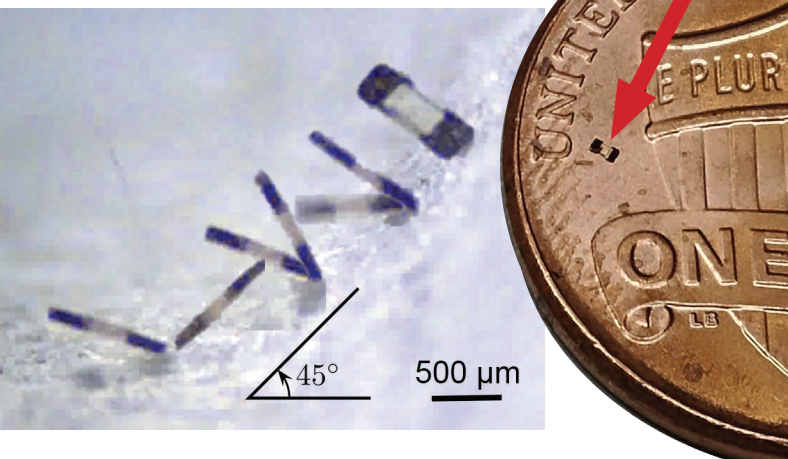
The device then mimics the reactions of actual tumors, when subjected to certain cancer therapies. Han's team demonstrated that the tumor-microenvironment-on-a-chip is just as effective as the current standards of animal-based testing. Han said, "This predictive ability for in-vivo drug response indicates its transformative potential for testing drug effectiveness."



ROBOTICS 🤖

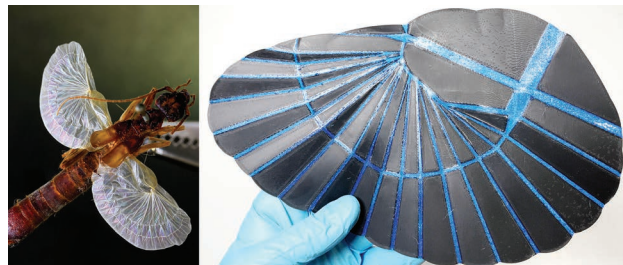
Microbots "tumble" over all terrains

David Capperelli and his Purdue ME team develop micro-robots, smaller than a millimeter, and propel them using an external magnetic field. Biomedicine has a great interest in micro-robots, because they can be injected into patients for super-focused drug delivery. But the human body is bumpy and sticky, with complex three-dimensional surfaces. Their solution? The micro-robots tumble, end-over-end, to clear obstacles. This allows them to successfully maneuver through both dry and wet environments, and over surfaces with bumps and trenches. They even climb inclines as steep as 60 degrees. "Robotics at the micro- and nano-scale represent one of the new frontiers in intelligent automation systems," Capperelli said.



SOLID MECHANICS 📐

Bio-inspired origami



The earwig is the origami champion of the animal kingdom. Its wing can fold to 10 times its size, with minimal muscle movement. Purdue ME professor Andres Arrieta has re-created this bio-inspired origami, using 3D-printed plastic with bistability. "Bistability not only allows this pattern to have two stable configurations (fully folded and fully deployed) but it also allows each of these stable states to sustain loads," Arrieta said, with no extra energy or actuator required for each state to lock. This energy-saving bistability could be built in to the designs of robots, packaging, spacecraft and biomedical devices.

SYSTEMS, MEASUREMENTS, & CONTROLS ⚖️

Holostream: real-time 3D streaming

3D imagery takes a lot of data, which is why real-time streaming of 3D video has been nearly impossible -- until now. Holostream, developed in the Purdue ME lab of professor Song Zhang, compresses 3D image data without substantially sacrificing the quality of the image. This allows live 3D streaming, even over the limited bandwidth of cell phone networks. The compression is variable and scalable, so it works with simple face-to-face chats, but also applications where image details are critical, such as manufacturing or medical imagery. "This technology could enable emerging applications that require high-resolution, high-accuracy 3D video data delivery, such as remote robotic surgery, or even 3D forensic analysis of a footprint sent from a crime scene," said Zhang.



Lithium-ion batteries require the right recipe

We've all seen horrific videos of lithium-ion batteries exploding and catching fire, such as in a laptop or electric car. Despite the ubiquity of these batteries, we know relatively little about how they work on a nano-scale. Purdue ME teams are working to change that.

"Rechargeable batteries are everywhere," said professor Partha Mukherjee. "We probably carry two or three portable electronics with us at all times. But the interactions between the different elements of the battery itself are still not clearly understood. Our research hopes to bridge that gap." His most recent study on the nano-scale interactions of lithium-ion batteries was featured on the cover of the journal *ACS Applied Materials & Interfaces*.

"It's like baking a cake," said Aashutosh Mistry, Ph.D. candidate. "How much dough should you use? How much cherry should you put in so that it tastes nice? In the same way, we look at the fundamental proportions, or the recipe, of these battery electrodes. Anything you change on the microscale ends up affecting the overall performance."

Sometimes their lab recreates the spectacular failures on purpose. For one test, a sample module of 24 cells (about the size of a brick) was purposely overcharged. One cell exploded, which led to a chain reaction where all the cells caught on fire. "In an electric car, there are several thousand of these cells, and these are located underneath your seat!" said Ph.D. candidate Daniel Robles, as he held a plastic bag of the charred remains. "That's why it's important to understand the fundamentals of these phenomena, so we can prevent it from happening."

Purdue ME professor Amy Marconnet approaches the problem from the thermal side. "Those chemical reactions generate power, but they also generate a lot of heat," she said. "This may cause one of the battery layers



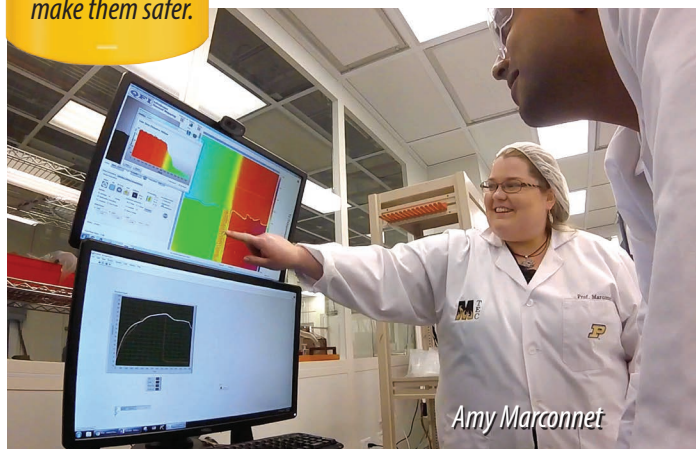
Don't let this happen to you!

Purdue ME teams are studying the nano-scale structures of lithium ion batteries to make them safer.

ENERGY STORAGE

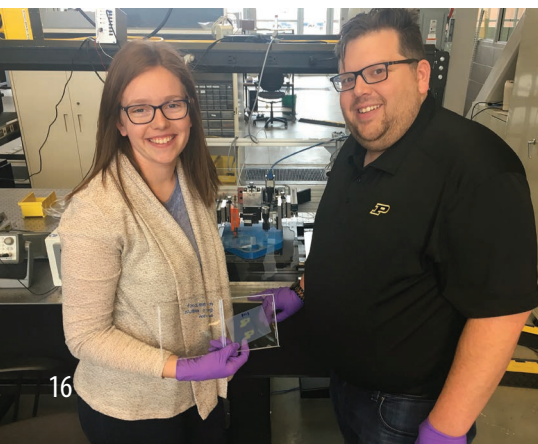
called the 'separator' to melt, which leads to a short circuit and possibly a fire or explosion. We measure the thermal conductivity of that separator layer, to determine just how hot it can get." Using high-resolution infrared thermography, Amy and her team have been able to quantify the heat properties of the separator, down to the micro-scale.

"We're still at a nascent stage in understanding these complex interactions," said Mukherjee. "But that's the key to our research. We connect what's happening at the micro- and nano-scale to the battery's performance, life, and safety. This is vital, as these batteries become more prevalent in portable electronics, vehicles, and large-scale electrical grids. This is a great and exciting time to do research in energy storage!"



Inkjet-printed thermite

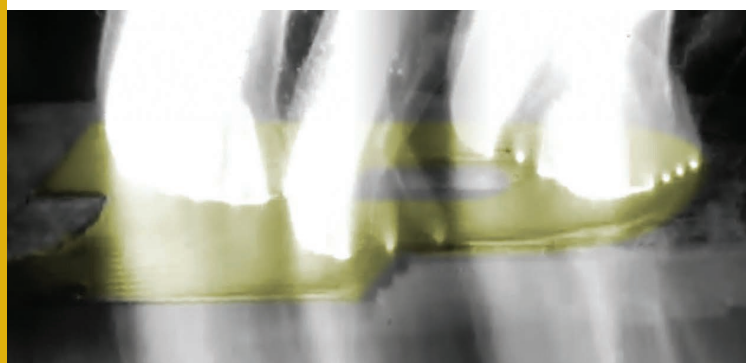
A multidisciplinary Purdue team have developed a method to deposit tiny amounts of energetic materials (explosives, propellants, and pyrotechnics) using the same technology as an inkjet printer. This allows energetic materials to be deposited with unprecedented levels of precision and safety. "Our solution is to combine two components as we're printing them," said Purdue ME professor Jeff Rhoads. "We



Allison Murray, Ph.D. candidate under professor Jeff Rhoads, developed a new inkjet-printing technique to deposit energetic materials safely and precisely.

MECHANICAL SYSTEMS

can have a fuel and an oxidizer in two separate suspensions, which are largely inert. Then with this custom inkjet printer, we can deposit the two in a specific overlapping pattern, combining them on a substrate to form nanothermite." The project, which has been published in the *Journal of Applied Physics*, has a team of 10 researchers and four faculty with wide-ranging expertise, from micro-electromechanical systems to energetic materials. "It's a defining feature of Purdue that professors from such different backgrounds can work together on a project like this."



Working 30 hours straight to design an elbow brace

BIOMEDICINE ♥

When Purdue ME professor Eric Nauman got the call from Purdue Sports Medicine, he was ready. "We've done concussion studies, and built braces and other assistive devices for athletes of all ages," he said. But this one was unique."

Isaac Haas, the 7' 2" center of the Purdue men's basketball team, had fractured his elbow during the NCAA tournament. He wanted to attempt to play the next game with a brace, but the NCAA wouldn't allow a device with "nonpliable material." That's when Nauman and his team of graduate students got to work in his lab, the Human Injury Research and Regenerative Technologies Lab (HIRRT).

They did some rapid prototyping, and experimented with many different types of padding materials. "It's the exact same process that we teach our students every semester," said Nauman. "Except we were doing it in 30 hours!"

What ultimately worked best was an old-school solution: leather. "Since we weren't allowed to use anything rigid, leather was the perfect material to prevent Isaac from locking his elbow out," said Nauman. One of his students actually did leatherwork as a hobby, and constructed the pieces



needed to complete the brace. "It's amazing to see these old and new technologies come together to get the job done."

So how do you size a brace for someone who is 7' 2"? "We didn't have any models in the lab that were anywhere near the right size," said Nauman. They attempted to simulate Haas' arm by dressing a student in many layers of bulky sweatshirts. One student even used the measurements of his leg to substitute for the thickness of Haas' arm!

Even though Haas never officially played with the brace, the rapid innovation made headlines on ESPN, CBS Sports, and other media that don't normally cover engineering. "The basketball team is a wonderful group to work with," said Nauman. That's why we gave pretty much every hour we had. We were driven to do the best job that we could for them."



Eric Nauman (middle) and his team pulled several all-nighters to design and build an elbow brace from scratch.

Smartphone-based lab to detect cholera

FLUID MECHANICS ♠

Katie Clayton (Ph.D. '17) has developed a smartphone-based handheld laboratory called PathVis, which can diagnose cholera in a water sample in just 30 minutes, instead of the usual three days.

Katie studied microfluidics with Purdue ME professor Steven Wereley. They discovered a way to analyze the seemingly random movements of particles in a small amount of fluid, and apply algorithms to determine specific properties of that fluid. "Then the question became, 'How do we take this out of the lab?'" said Katie.

"How do we make this into something that can actually help people?"

Collaborating with Purdue's Weldon School of Biomedical Engineering, they focused on cholera, a water-borne infectious disease that affects millions in developing countries. Typical tests for cholera take more than three days, putting many people in danger. Katie's team built a portable solution, converting a smartphone's camera into a mobile laboratory. They also developed an app, which verifies the results and charts them on a map using the phone's GPS.

The resulting device, PathVis, has garnered worldwide attention. The team received a \$300,000 grant from Vodafone, and Katie has gone from scientist to entrepreneur. "It's so exciting," says Katie, "helping people's lives, and getting to do it with science? There's nothing cooler than that!"



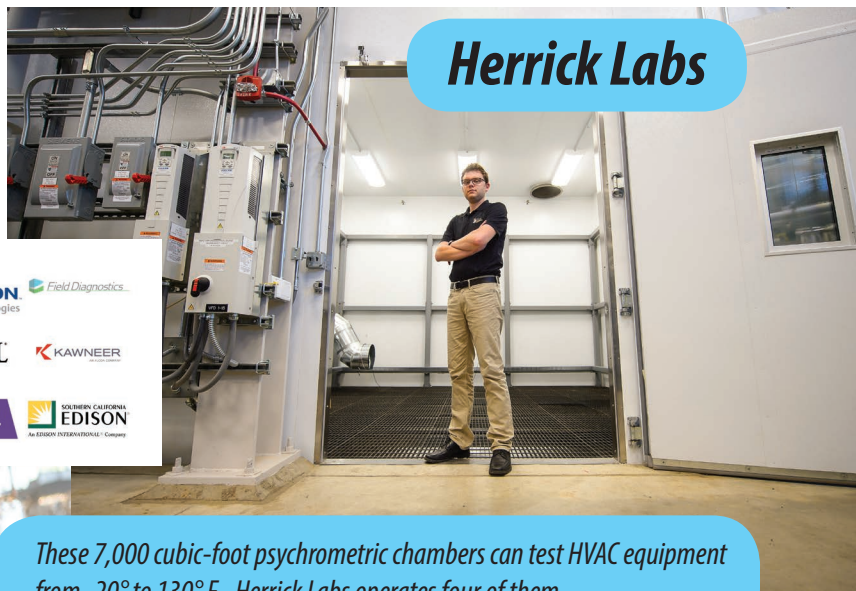
Katie Clayton (middle) and a team of mechanical and biomedical engineers developed a smartphone-based portable lab to detect cholera.



WORLD CLASS

Keeping it cool! The largest academic HVAC lab in the world

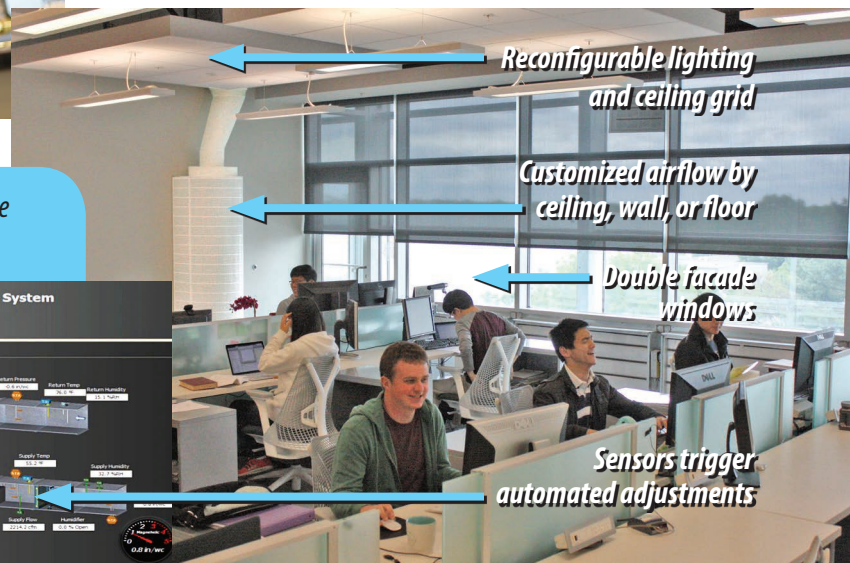
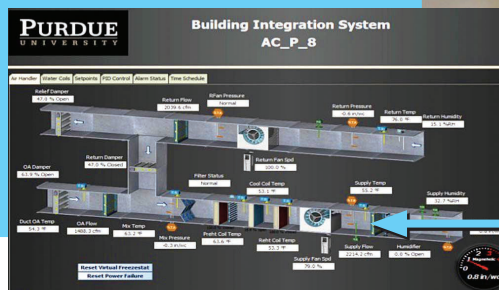
Founded in 1958, Purdue's **Herrick Labs** is the premier academic research center for refrigeration and air-conditioning. All aspects of human-building interactions can be precisely monitored, from energy usage to human comfort. It's no surprise that dozens of industry partners collaborate with Herrick on world-changing research.



Herrick Labs

These 7,000 cubic-foot psychrometric chambers can test HVAC equipment from -20° to 130° F. Herrick Labs operates four of them.

At Herrick Labs, the building is the laboratory. These "Living Lab" office spaces allow every environmental factor to be carefully controlled, compared, and studied. More than 1,000 sensors throughout the building monitor everything from the speed of the ventilation fans to the temperature of the drinking fountains.



Reconfigurable lighting and ceiling grid

Customized airflow by ceiling, wall, or floor

Double facade windows

Sensors trigger automated adjustments

Herrick's expertise attracts visitors from around the world. Their biennial conference on compressors and refrigeration draws more than 800 industry experts from 30 countries. Purdue ME students at Herrick frequently collaborate, like with these students from Dresden, Germany (right).



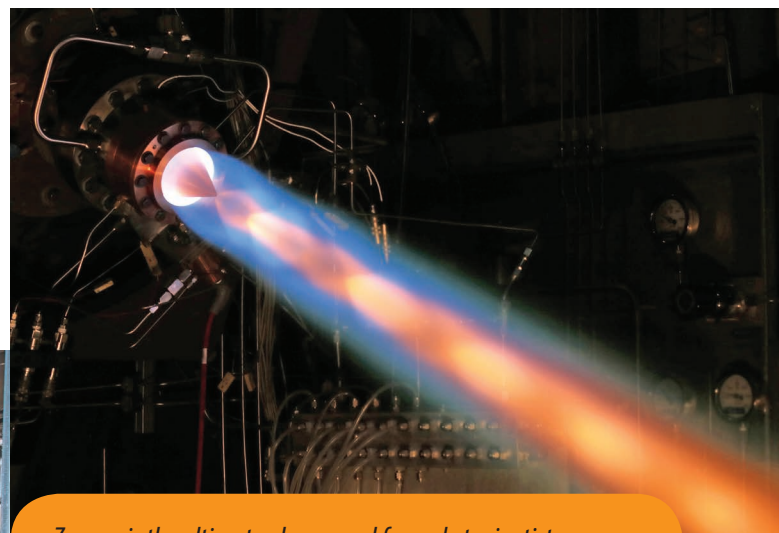
SS FACILITIES

Blast off! The largest academic propulsion lab in the world

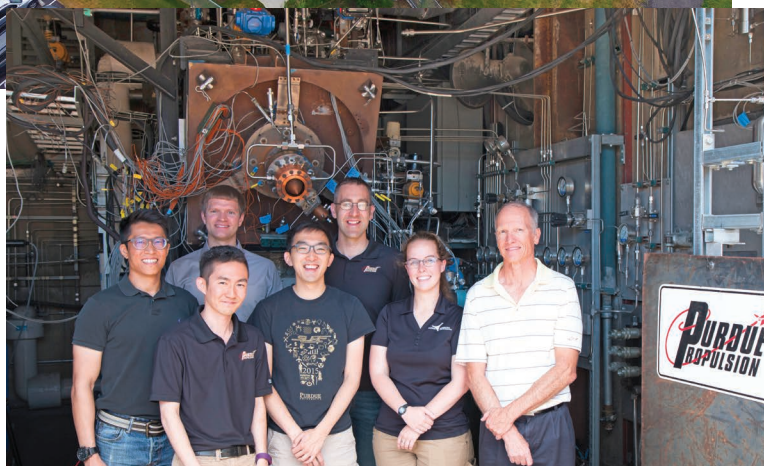


Zucrow Labs

Set on 24 acres next to Purdue Airport, **Zucrow Labs** is the largest academic propulsion lab in the world, specializing in high-pressure combustion and gas turbines. More than 150 Purdue students do research there, many moving on to NASA, SpaceX, and Blue Origin.



Zucrow is the ultimate playground for rocket scientists, testing rocket engines since 1948. Today, their test cells and infrastructure support the highest pressures and temperatures possible, and their laser diagnostics labs measure the combustion hundreds of thousands of times every second. Professor Stephen Heister's group is working on the rotating detonation engine (RDE).



Modern aerospace depends on high-speed turbines and compressors, and Purdue ME professor Nicole Key tests them at Zucrow.

Energetic materials (propellants, explosives, and pyrotechnics) are a Zucrow specialty. Brandon Terry (Ph.D. '15) developed a new solid rocket fuel while studying at Zucrow Labs, and formed a company (Adranos Energetics) to market it.



HYDRAULIC-POWERED BICYCLE



Can you move a bike using just hydraulic pumps and motors? A Purdue ME team proved it by winning the Fluid Power Vehicle Challenge.

“Usually fluid power is used for heavy-duty applications,” says professor Andrea Vacca, the team’s advisor. “So designing something compact, like a bicycle, is a real challenge.”

Students designed and built an original bike frame to function as the hydraulic reservoir, added an accumulator for propulsion without pedaling, and even developed a mobile app to monitor hydraulic pressure.

“Purdue has the largest academic fluid power lab in the nation,” says Vacca. “Our students have the ability to tackle any problem, big or small.”



Watch videos and bonus content at:
purdue.edu/ME/magazine