UNIVERSITY OF DELAWARE

ENGINEERING

MECHANICAL ENGINEERING

FALL 2020

THE DESIGN STUDIO 2.0

WE'RE UPGRADING OUR SPACE—SEE HOW

INSIDE

CHAIR'S MESSAGE

While 2020 has brought unprecedented challenges, the Department of Mechanical Engineering at the University of Delaware remains strong and resolute.

We responded to COVID-19 by swiftly pivoting our classes to virtual offerings. Many of our faculty were already experienced with offering online classes routinely, so we were ready for this challenge. Based on an idea suggested by Professor Suresh Advani, Professor Jenni Buckley even created a do-it-yourself Zoom protocol for proctoring exams that has gone viral on YouTube and helped the academic community nationwide. Check it out at www.udel.edu/007727.

Members of our department also designed the "HensNest", a novel 3D-printable face mask that provides better protection than many other homemade masks. (Read more about it on page 8.)

Our department is growing and poised to emerge stronger than ever in 2021. Our undergraduate program continues to be in high demand with strong enrollment year after year. We have added eight new faculty in the past three years, and our faculty size has grown to 30, the largest in the history of our department. What's more, our early-career faculty are winning major awards and grants and establishing themselves as future leaders in the field of mechanical engineering.

In Fall 2019, we saw the largest PhD and MS enrollments in the history of our department. We also launched the master of science in robotics in collaboration with the Department of Computer and Information Sciences and the College of Engineering.

In 2020, faculty in our department established two new research centers. Directed by Professor Bert Tanner, the Center for Autonomous and Robotic Systems (CARS) is engaged in answering questions at the intersection of systems theory, automatic control, and artificial intelligence with applications for health, the environment and more. Directed by Professor Andreas Malikopoulos, the Sociotechnical Systems Center (SSC) aims to use system-based approaches to address complex challenges at the intersection of technological, social, and institutional dimensions.

As we look to the future, we are excited about the growth of our department, especially our design-infused undergraduate curriculum. We received a $987,000 grant from Unidel to catalyze the renovation of our Design Studio, the heart of our undergraduate program. On page 5, you'll get a glimpse at what we have planned. We are also working to infuse more computational elements throughout our curriculum.

As an engineer, continuous improvement is important to me. In July 1, 2020, I began a two-year term on the American Society of Mechanical Engineers (ASME) Department Head/Chair Executive Committee. I am working with other mechanical engineering department chairs across the nation to shape the future of mechanical engineering education.

To keep up with our news and events and learn how to get involved with our department, visit me.udel.edu and join the conversation on the social media channels listed on this page.

AJAY PRASAD

DEPARTMENT CHAIR
ENGINEERING ALUMNI
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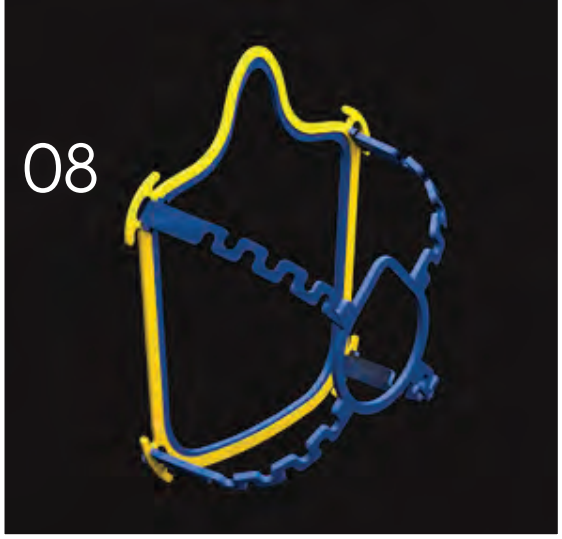
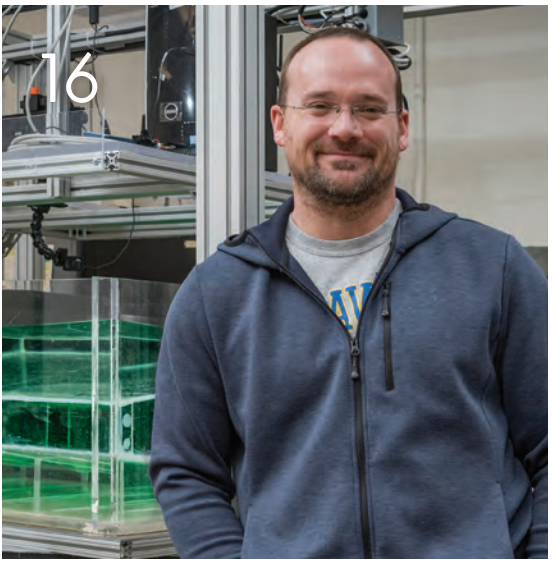




IN THIS ISSUE

AT A GLANCE

693

STUDENTS
22% growth over 5 years

UNDERGRADUATE
592 students
in Spring 2020

Degree
Bachelor's in
Mechanical Engineering

Minors
Biomechanical and Integrated Design

Concentrations
Aerospace, Automotive Engineering, and Manufacturing Systems

GRADUATE
101 students in Spring 2020

Degrees
Ph.D. in Mechanical Engineering

Master of Science in
Mechanical Engineering
(thesis or non-thesis, campus or online)

Master of Science in Robotics

Graduate Certificate in Composites Manufacturing and Engineering

Graduate Certificate in
Composite Materials

4 + 1 Program BME/MSME

CORE RESEARCH AREAS
Biomechanical Engineering, Clean Energy and Environment, Composites and Advanced Materials, Nanotechnology, Robotics and Controls

FACULTY & RECOGNITION

6

Named Professors

Suresh Advani
George W. Laird Professor of Mechanical Engineering

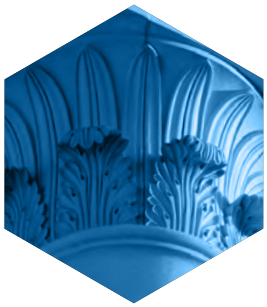
Thomas Buchanan
George W. Laird Professor of Mechanical Engineering

Tsu-Wei Chou
Unidel Pierre S. du Pont Chair

John W. Gillespie Jr.
Donald C. Phillips Professor of Civil and Environmental Engineering

Andreas Malikopoulos,
Terri Connor Kelly and John Kelly Career Development Professor

Ajay Prasad
College of Engineering
Alumni Distinguished Professor

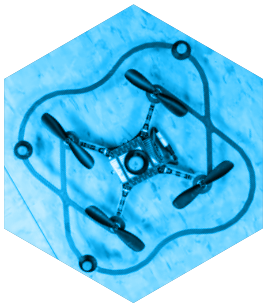


FACILITIES

23,620 square feet
of lab and supporting facilities

2,000 square feet
of teaching facilities

3,570 square feet
of student design and collaboration space



POINTS OF PRIDE
Design Studio
Robotics MS Degree
Composites Certificates

RESEARCH

$6.1M
in sponsored research expenditures

Major Funders
Advanced Research Partnership-Energy (ARPA-e, Air Force Office of Scientific Research (AFOSR), Army Research Laboratory (ARL), DefenseAdvanced Research Projects (DARPA), DelDOT, DNREC, Federal Transit Administration, Federal Highway Administration, NASA University Leadership Initiative, National Academies of Sciences, Engineering and Medicine, National Institutes of Health (NIH), National Natural Science Foundation of China, National Science Foundation (NSF), Office of Naval Research (ONR), U.S. Department of Energy (DOE), UT-Batelle

Industry/Research Partnerships
Arkema, Boston University, Clemson University, Composites Automation, Delaware Economic Development Office, Drexel University, DuPont Company, ExxonMobil Corporation, Harvard University, Huntsman, Johns Hopkins University, MCET Technologies, Morgan State University, Portland State University, Purdue University, Robert Bosch GmbH, SGL Carbon, Southern University, STF Technologies, TPI Composites, UT-Batelle, University of California, Berkeley, University of Michigan, University of Pennsylvania, University of Southern California, University of Texas at Dallas, Virginia Tech

EXCELLENCE IN DESIGN EDUCATION

THE DESIGN STUDIO

Over the last decade, our Design Studio makerspace has become the beating heart of our academic program, a place where mechanical engineering students gather to design, build, iterate, and make lifelong friends along the way. We've even earned national recognition for the courses that take place here. Now, we are upgrading the first floor of Spencer Laboratory to create an unparalleled space for mechanical engineering education. Read on to see what's in store.

We're upgrading our signature space →

EXCELLENCE IN DESIGN EDUCATION

We're building a bigger, brighter, better facility to train our students in design and manufacturing.

Welcome to the Future of Spencer Lab!

We are working with DIGSAU, a renowned architectural firm based in Philadelphia, to redesign the first floor of Spencer Laboratory and create a new, improved Design Studio.

As engineers, nothing excites us more than the opportunity to redesign, optimize, and re-imagine the possibilities. We are building the world's next great academic engineering makerspace.

Before we dive in to the new plans, here's what you should know about our Design Studio as it stands today. Our Design Studio is a one-of-a-kind academic makerspace designed specifically for engineering education. It is the most established and heavily used makerspace at UD and among the most prominent engineering-focused academic makerspaces in the nation.

The Design Studio is the training ground for 700 mechanical and biomedical engineering students who complete more than 250 prototypes per semester. More than 20 undergraduate and graduate courses utilize the space each year.

With guidance from professional staff and teaching assistants, students gain practical experience and develop lifelong skills that they carry forward through their careers

So why does the Design Studio need an overhaul? Let's go back to the beginning. The Design Studio began in 2011 as a grassroots effort by faculty, staff, and undergraduate students. We retrofitted existing spaces, including vacant classrooms and research labs.

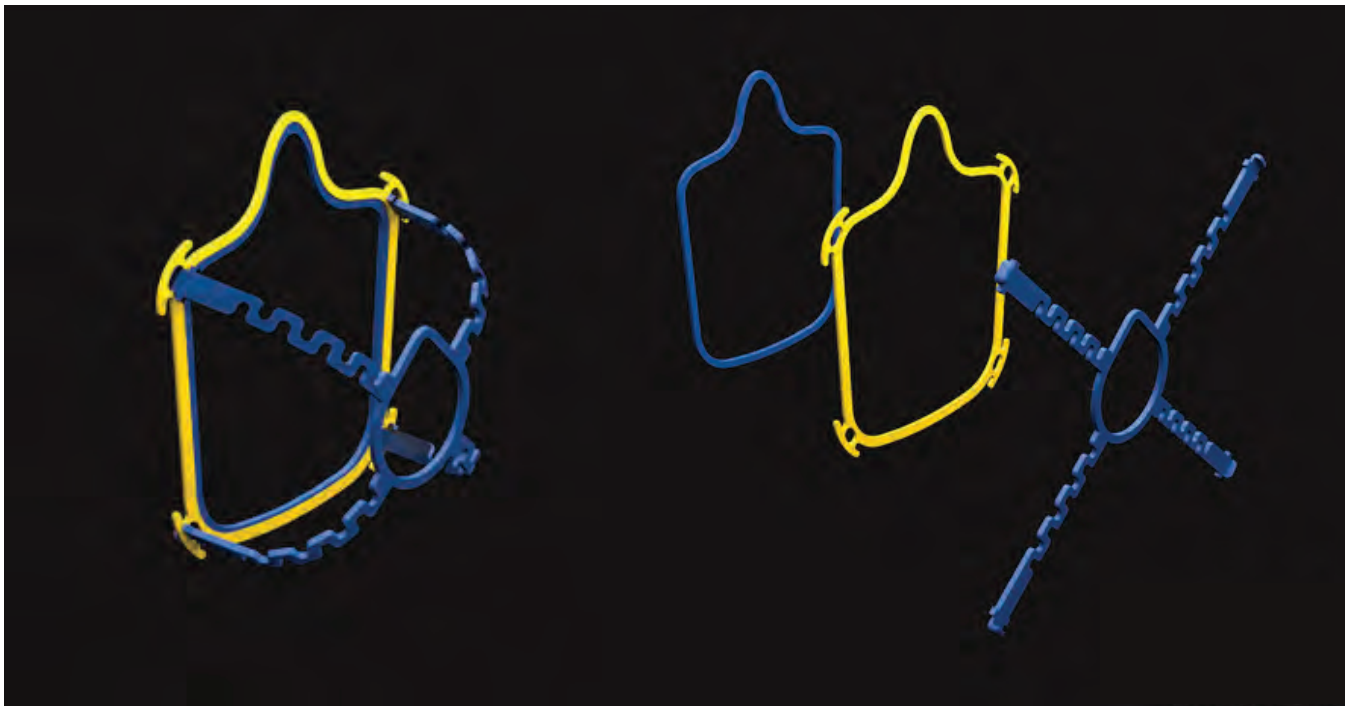
Since then, the Design Studio has evolved into a home away from home for students, a place where they build skills and forge lasting connections. Students gather in this space to review problem sets, hold meetings, and more.

Now, our program is expanding, and we have outgrown our space. Our equipment, personnel and programming are among the best in the nation, but our space does not reflect our excellence in these areas. We need more space to safely educate engineers as they learn to use equipment from bandsaws and drill presses to laser cutters and 3D printers. We need to connect rooms that are now disconnected to improve workflow for students. We would like to install more windows so that visitors to Spencer Lab can see students' great work.

The new plans will allow us to increase the Design Studio's footprint from 11,500 square feet to 13,300 square feet. Through our renovations, we plan to:

- Expand our low-precision manufacturing core space, where students prototype in wood and plastic, by 50 percent to address current and future occupancy needs.
- Transform our high-precision manufacturing work area, where students perform industry standard metalworking operations, by repositioning equipment for optimal accessibility.
- Make our digital fabrication area, which features 3D printers, scanners and laser cutters, the centerpiece of the studio.
- Expand our student collaboration spaces, install more windows, and add dedicated meeting rooms, enabling students to do their very best.
- Update our instructional spaces with optimally sized lab benches.

Please reach out to Jenni Buckley (jbuckley@udel.edu) if you have feedback on our plans.



MAKING A DIFFERENCE

Mechanical engineers respond to crisis with creativity, compassion

While the coronavirus pandemic has upended our lives in many ways, the pandemic cannot stop the compassion and creativity of mechanical engineers at the University of Delaware.

In mid-March, research labs and health clinics across campus donated thousands of pieces of personal protective equipment (PPE), including surgical masks and gloves, N95 respirators, lab coats and Tyvek disposable gowns to the Delaware Emergency Management Agency for distribution to those front line responders in greatest need across the state.

Since then, virtual networks of UD makers have emerged to answer the call for more PPE to help police officers, firemen, health care workers, pharmacy and grocery store workers, perhaps family and friends in your own neighborhood.

A face mask like no other: The HensNest

When UD's Jenni Buckley answered her cell phone, she could immediately tell that her friend, Lisa Lattanza, was worried. Dr. Lattanza, chair of orthopedics and rehabilitation at Yale School of Medicine, had already seen 15 cases of COVID-19 by late March, and she was concerned her hospital could run out of face masks. Her voice was urgent.

"What can you create for me fast?" she asked Buckley, who is an associate professor of mechanical engineering and director of the Design Studio at UD. Buckley and Lattanza co-founded the Perry Initiative, which sponsors outreach programs to inspire young women to be leaders in engineering and medicine.

Meanwhile, at his home in Salem, New Jersey, Whitney Sample, co-director of UD's Design Studio, received an email from A.I. duPont Hospital for Children, asking for help finding more face masks.

Previously, Sample had worked at the hospital, where, among other innovations, he co-invented an exoskeleton to give children with debilitating conditions such as arthrogryposis the ability to lift their arms.

Sample and Buckley discussed ideas with Lattanza at Yale and colleagues at A.I. duPont. They began scouring face mask designs on GrabCAD, an open-source forum of over 7 million engineers, designers, manufacturers and students.

"The designs that were out there were a great start, but there were issues with functionality and we were in a unique position with our training and resources to tackle that," said Sample, an industrial designer by training, with 20 years of experience in the medical field.

The clinicians wanted a mask that sat out from the face, so that breathing humid air would not impact the integrity of the filter. So Sample and Buckley and their team, which included faculty, students and clinical partners, set out to build a better face mask. The "HensNest" was born.

Sample's idea was to pursue a lofted wireframe design that could be assembled into a mask like a pop-up card. He began with an open-source design called the "DIY Face Mask" by Mark Fuller at GE Additive. Then the UD team added their innovation twists and put the design back out on GrabCAD and the National Institutes of Health (NIH) 3D Print Exchange for other engineers to hack.

The HensNest consists of only a few plastic pieces that snap together. They include the "face hoop," the X-shaped "spider" that gives the mask its convex shape, and a triangular containment hoop that holds a swatch of filter material (Sample has used part of a HEPA furnace filter) neatly tucked into place. The triangular frame fits snugly around the bridge of the nose, the cheeks and under the chin, while the convex shape positions the filter comfortably off the nose and lips.

Major manufacturers have stepped up to the plate to help mass produce HensNest face masks. Stratasys Corp and NegriBossi together produced 30,000 face mask frames at no or reduced cost; and Procter and Gamble and WB Mason have donated goods for packaging. Donate Delaware, a local nonprofit organization, registered as a 501(c)(3), packaged and distributed the face masks, with Little Goat Coffee and The Journey Church serving as local distribution centers.

A SUCCESSFUL MOVE TO ONLINE LEARNING

University-wide team effort brings all but two of 6,422 course sections online in just two weeks

In response to COVID-19, UD moved all but two of 6,422 course sections online in just two weeks in March.

The flexibility and ingenuity of faculty was crucial to this smooth migration. In mechanical engineering, a "buddy system" paired faculty more experienced with online learning with those who were not," said associate professor Jenni Buckley. Led by chair Ajay Prasad, the department also repurposed a department-wide teaching resources Canvas page as an open forum where faculty could share tips, tutorials and examples.

"Both of these resources were really popular because they made faculty who might have struggled a bit feel like they weren't alone and there were trusted peers who could help," Buckley said. "It has been really amazing to Ajay and me to see how our more senior faculty are stepping up to the plate when it comes to adopting new technologies and teaching techniques."

To administer long-form written exams, Professor Suresh Advani came up with a "hack" of proctoring using Zoom that a team then scaled into a protocol that could be used in classes.

SENIOR DESIGN

THRIVING IN A REAL-WORLD ENVIRONMENT

Through Senior Design, engineering students flex their skills

In fall 2019, Senior Design brought together 141 students, including all seniors majoring in mechanical engineering and biomedical engineering as well as some students majoring in electrical and computer engineering and civil and environmental engineering. The students were divided into 36 teams guided by 13 faculty advisors. Projects were sponsored by industrial and academic partners.

"What stood out most in senior design this year was the excellent interdisciplinary integration and teamwork, which enabled engineering seniors to make the best possible prototypes in the shortest possible time," said Ashutosh Khandha, an assistant professor of biomedical engineering. "It was exhilarating to see students working with industry, business and clinical sponsors, and thriving in a real-world environment."

Mechanical engineering senior Matthew Hardie worked on a project to develop a universal tooling interface for planetary excavation robots. The project was sponsored by the Delaware Space Grant Consortium.

Hardie was drawn to the project because he knew it would incorporate computer aided design and mechanism design, areas in which he is already skilled, while introducing new challenges at the same time.

"The fact that this device has to hold up to the harsh environments on other planets is what made the project new and exciting," said Hardie.

The team came up with 20 or more ideas before they decided on their final concept, a design that would overcome reliance to dust while meeting load, size and weight requirements.

"Every year, I am more and more impressed with the sophistication of the prototyping," said Jenni Buckley, associate professor of mechanical engineering. "Just when I think we've peaked as a program, the students again exceed the mark. I think our emphasis on hands-on fabrication and computer-aided design in the early years of our curriculum is paying off. By the time these students are seniors, they're able to produce a Gen 1 prototype by midterm, field test it, and make improvements by the time of the showcase in December. It's impressive, and I think this early, consistent focus on design is what makes all of the difference."

UD Football Defensive Back Brian Dennis helps students brainstorm ideas at the HensWEAR-sponsored brainstorming event that led to a senior design project.

NEW APPROACH TO AN OLD PROBLEM

University of Delaware faculty and Athletic Department staff were looking for a new solution to an old problem for athletes, especially football players — hamstring pulls. Hamstring strains are common in football players. They're also a labor intensive injury for athletic trainers to deal with because the typical treatment involves taping athletes to help support the hamstring and reduce discomfort.

HensWEAR, a group of researchers and partners– including several mechanical engineering faculty–is developing innovative wearable technology and materials (Learn more on Page 18). What began as a brainstorming session with students from across campus including athletics became a senior design project sponsored by HensWEAR.

Assistant Head Athletic Trainer Brandon DeSantis challenged senior design students to find a way to create a new device for hamstring rehabilitation to reduce the need for extensive taping. "Senior design is a good way to really get our seniors, our highly qualified students, our engineers-in-training, their first exposure to a real-world project," said Adam Wickenheiser, Associate Professor of mechanical engineering and the advisor for the project.

A group of four senior engineers, Madison Knox, Melody Cerro, Joseph Lockard and Jacob Lubsen, designed, produced and tested a prototype device. While the original athletic training device was really just a hodge-podge of tape and wrap, the group's design was one solid piece that athletes can put on themselves in under a minute. A hip brace is sewn to a thigh compression sleeve, while a resistance band is connected to an ankle sleeve, with several D-rings on the waist allowing for size adjustments.

"It's a lot less cumbersome, it's a lot sleeker. It's just a better design," DeSantis said.

"Everyone really just does have a common goal of producing new and innovative wearable devices, whether it's for athletes, or the general population, or special populations," DeSantis said. "We got connected with [HensWEAR] and since then we've been working on creating different things. We've had a couple different prototypes for a couple different projects, but it's stuff that we wouldn't be able to do on our own."

BUILDING ON THEORY—WITH BIKES

Engineering students design and fabricate wooden bicycles, partner with local bike shop

Students showed off their creations in UD's new MakerGym.

Students in the sophomore level mechanical engineering course Statics, the study of forces acting on a system at rest or at a constant velocity, recently designed and fabricated wooden bicycles that would make Archimedes proud.

In partnership with Wooden Wheels Service & Repair, a bike shop located in Newark, Delaware, students were tasked with creating functional bike frames made entirely out of wood in the fall of 2019.

This hands-on project was the brainchild of Jenni Buckley, an associate professor of mechanical engineering. Buckley has been recognized nationally for her teaching methods and was named a member of the American Society for Engineering Education's "20 Under 40" in 2018.

"Most programs at other universities teach Statics as a 'theory-only' course," said Buckley.

"We teach the theory here, too, but we also give the students the opportunity to apply what they learned in real-world design situations."

Wooden Wheels was an ideal partner for the project. Buckley, a former competitive cyclist, is a long-time customer of the shop.

"Jenni was talking about this wooden bike project, and we're Wooden Wheels, so it all just made sense," said Wooden Wheels co-owner

Robbie Downward. The winning bike, as determined by a panel of judges, were displayed at the Wooden Wheels shop.

The 160 students in the course, working in teams of four, consulted with the owners of Wooden Wheels on their bike frame designs and then utilized the Design Studio in Spencer Lab to make the frames. In the Design Studio, a nationally recognized academic makerspace dedicated to undergraduate engineering education, students were assisted by a team of teaching assistants, upperclassmen engineering students.

Each team was given a pre-defined amount of wood and components, and they applied the engineering theory that they had learned in class to determine the risk of structural failure for their bike frames.

"We had to keep in mind the internal forces," said student Sarah Ott. "If you apply a force on the seat and two forces at each wheel, you have to make sure the inside doesn't cave in or just break in half while you're on the bike."

The students used computer-aided design, computer numerical control machines and more to bring their designs to life.

Jessica Betz, an honors mechanical engineering student, and her teammates were initially skeptical about whether their bike would really hold a person's weight. "As we kept going and making adjustments and reinforcements, it really helped us solidify what we were learning in the classroom by actually building it," said Betz.

Many of the students' initial designs required adjustments. After all, design and fabrication are iterative processes.

"Students had to make on-the-fly adjustments, which is what engineers are supposed to do," said Buckley.
By working in teams, students could combine their strengths.

To close the semester, students showed off their bikes to a team of judges in UD's new MakerGym, a transdisciplinary makerspace, on December 4, 2019. Some students even opted to ride their bikes in the parking lot.

"Some students have more math experience and less prototyping experience, and vice versa," said Buckley. "A project like this levels the playing field and shows students that different skills are valuable. Through teamwork, students come to appreciate that there is room for everybody."

BUILDING A STRONGER WORLD

After an early look at UD, Colleen Murray recognized for excellence in composite materials research

After learning about composite materials at age 12 while attending UD's K-12 Engineering summer program, UD graduate student Colleen Murray is giving back to young, future engineers by working as a mentor in the same program

Many people spend years searching for their calling, but Colleen Murray was only 12 years old when she discovered her passion for materials engineering. She was fascinated by the surprisingly strong materials, such as fiberglass and carbon fiber laminates, that she was given to build a miniature bridge during a UD K-12 Engineering summer camp.

A decade later, Murray developed sensors to keep real bridges safe as a graduate student in materials science and engineering and a researcher at UD's renowned Center for Composite Materials (CCM).

Murray received the 2019 Harold Giles Memorial Scholarship from the Society of Plastics Engineers (SPE) Composites Division. At the 2019 Society for the Advancement of Material and Process Engineering (SAMPE) University Research Symposium, Murray won first place in the MS category. .

After Murray's early introduction to materials engineering, her interest only grew. In high school, Murray — a native of Delaware, — interned at CCM through the UD K-12 Engineering High School Internship Program. Later, as an undergraduate student in mechanical engineering at UD, she continued to study composites.

Most recently, under the guidance of Erik Thostenson, associate professor of mechanical engineering, Murray studied carbon nanotube-based sensors that can be used for wearable sensors, gait analysis, and monitoring crack growth in infrastructure. Her research suggests that carbon nanotubes can be used to track changes in the deformation of laminate materials and even suppress the growth of cracks.

Murray's passion for making the world a better place extends beyond engineering. She was part of a team of students that established Blue Hen Bounty, UD's food pantry for food-insecure students. She also participated in outreach programs, helping UD's Formula SAE student team incorporating more lightweight composite materials into their racecar, and more.

DRIVEN TO DISCOVER

Mechanical engineering major Jeffrey Neumann and computer engineering major Ahmad Tamimi are involved in the NASA CURIE mission, which is being led by researchers at the University of California, Berkeley and the University of Delaware. CURIE — which stands for Cubesat Radio Interferometry Experiment — will use small satellites, about the size of a toaster oven, to gather data about the super-charged plasma that radiates from the sun, especially during solar flares. These violent eruptions of high-energy radiation can kill astronauts in space and damage electrical systems here on Earth.

UD undergraduates Jeffrey Neumann (left) and Ahmad Tamimi are working on the power system and communications software for the ground stations for NASA's CURIE mission.

NSF GRADUATE RESEARCH FELLOWSHIPS

Students earn support for future work

In 2019 and 2020, UD mechanical engineering doctoral students received NSF Graduate Research Fellowships (GRFP).

"The GRFP program provides the most promising scholars with the resources needed to pursue research topics they find inherently interesting," said David Martin, associate dean for research and entrepreneurship in UD's College of Engineering. "The projects they work on often are the most challenging and rewarding, since they can reach out in areas where the ideas go beyond the support of traditional funding mechanisms. We are proud that so many of our students and alumni have been able to take advantage of this incredibly prestigious and competitive opportunity."

Luke Nigro received an NSF GRFP in 2019 to further develop and refine the state of ankle-foot orthosis (AFO) prescription and design.

Rebecca Davis received an NSF GRFP in 2020. She is designing an exoskeleton that can induce safer impact conditions for soldiers jumping from large heights.

IN THE LOOP

Research on unusual ocean currents could save lives, benefit industries

Western boundary currents, the strong intense currents seen on the western boundary of each major ocean basin, such as the Gulf Stream or the Kuroshio current, transport significant amounts of heat from the equatorial regions towards the poles, thus playing a major role in Earth's climate, and are important to the life-cycles of many ocean species. Despite their great importance, many unanswered questions concerning their fundamental dynamics remain, particularly concerning their stratified, or layered, nature.

Joe Kuehl, UD associate professor of mechanical engineering, with graduate student Charles McMahon, and Vitalii Sheremet, a scientist at the University of Rhode Island, recently shed new light on this long-standing oceanographic problem. In an article published in the journal *Fluids*, they derived, solved and validated a new numerical formulation for accounting for viscous, layer western boundary current systems.

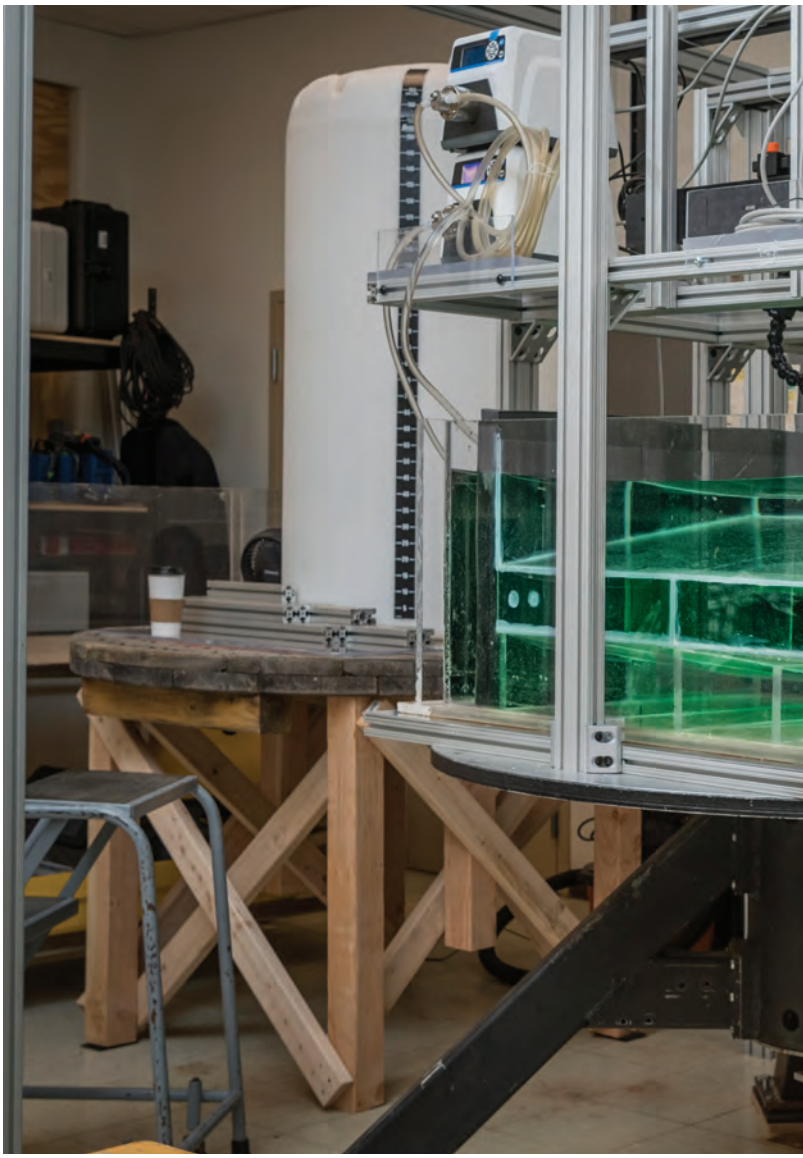
An essential tool for their research is a water-filled rotating tank on a table at UD that simulates the Earth's rotation to study ocean currents. It's one of only a handful in operation in the U.S.

"By rotating the tank of water, you can basically study a system that mimics the flow of water in the ocean," he said.

Kuehl also is using the rotating tank, coupled with field studies, to explore puzzling currents in the Gulf of Mexico. From Hurricane Katrina to the Deepwater Horizon oil spill, disasters happen in the Gulf of Mexico — and they are exacerbated when powerful currents carry torrents of water to unexpected places. Before the next catastrophe, researchers want to improve their understanding of the currents that flow through the gulf.

One of the most important currents in the Gulf of Mexico is the Loop Current. Hurricanes feed off warm surface waters in the ocean, and the Loop Current is a huge energy source.

"The Loop Current is one of the major factors affecting the strength of hurricanes in the Gulf of Mexico," said Kuehl. "For instance, with Hurricane Katrina, the models did a very poor job of estimating Katrina's strength."



The ultimate goal of this work: understanding, environmental stewardship, and helping to safeguard Gulf Coast communities.

This research is funded by the National Science Foundation and the National Academies of Science, Engineering and Medicine: Gulf Research Program.

Read the full article at https://doi.org/10.3390/fluids5020063

Left: Through experiments that simulate the famous Loop Current in the Gulf of Mexico, Professor Joe Kuehl determined that loop currents can exhibit multiple states and behavior dependent upon their past behavior.

Below: Graduate student Charles McMahon adds dye to the system.

FROM THE MINDS OF HENSWEAR

UD researchers are developing smart wearables, including an upper-body active exoskeletal garment that would help stroke survivors move their limbs with the help of embedded motors and cables, overseen by a computer that senses when the patient needs help.

As director of Neuromuscular Biomechanics Lab, Jill Higginson, professor of mechanical engineering, is using human movement analysis and musculoskeletal modeling to pinpoint placement of sensors on the suit, a crucial step for ensuring that patients' receive just the right amount of help from the motors and cables.

Fashion and apparel studies professor Huantian Cao is "putting the pieces together" into a garment that is comfortable despite its high-tech components and has an aesthetic appeal.

Once equipped for motor-assisted movement, the garment needs some way to measure and monitor those movements. That's where HensWEAR relies on mechanical engineering professor Erik Thostenson and recent doctoral graduate Sagar Doshi, who are developing a method for turning the fabric itself into a measurement device. Once coated with carbon nanotubes, the fabric becomes capable of measuring movement through tiny changes in electrical resistance when stretched.

Biomedical engineering professor Fabrizio Sergi, who has a joint appointment in mechanical engineering, is working on computer algorithms that will be the "brains" of the system of motor-driven pulleys and cables that will sense when to give a mechanical boost to a patient's movements. Grad students Steve Buchanan and Cheyenne Smith helped push it all forward.

Mechanical engineering professor Michael Keefe is analyzing how garments interact and bend with human movement. Mechanical engineering professor Kun (Kelvin) Fu is developing new fiber-based batteries (see opposite page for more on Fu).

HensWEAR (https://sites.udel.edu/henswear/) is bolstered by research from other top UD professors across colleges.

An active exoskeletal garment, developed by faculty across UD, would help restore upper-body mobility for stroke survivors. Mechanical actuators within the device push and pull on cables that run through the sleeves, serving as artificial ligaments, muscles and tendons. The pushing and pulling of the cables helps raise and lower the wearer's arms, while computer algorithms sense when the patient needs an assistive boost, and how much help to provide.

Kun (Kelvin) Fu, an assistant professor of mechanical engineering at the University of Delaware, has used a 3D printer to make pure carbon nanotube (CNT) architecture that are lightweight, strong, and highly porous.

LIGHTER, STRONGER MATERIALS

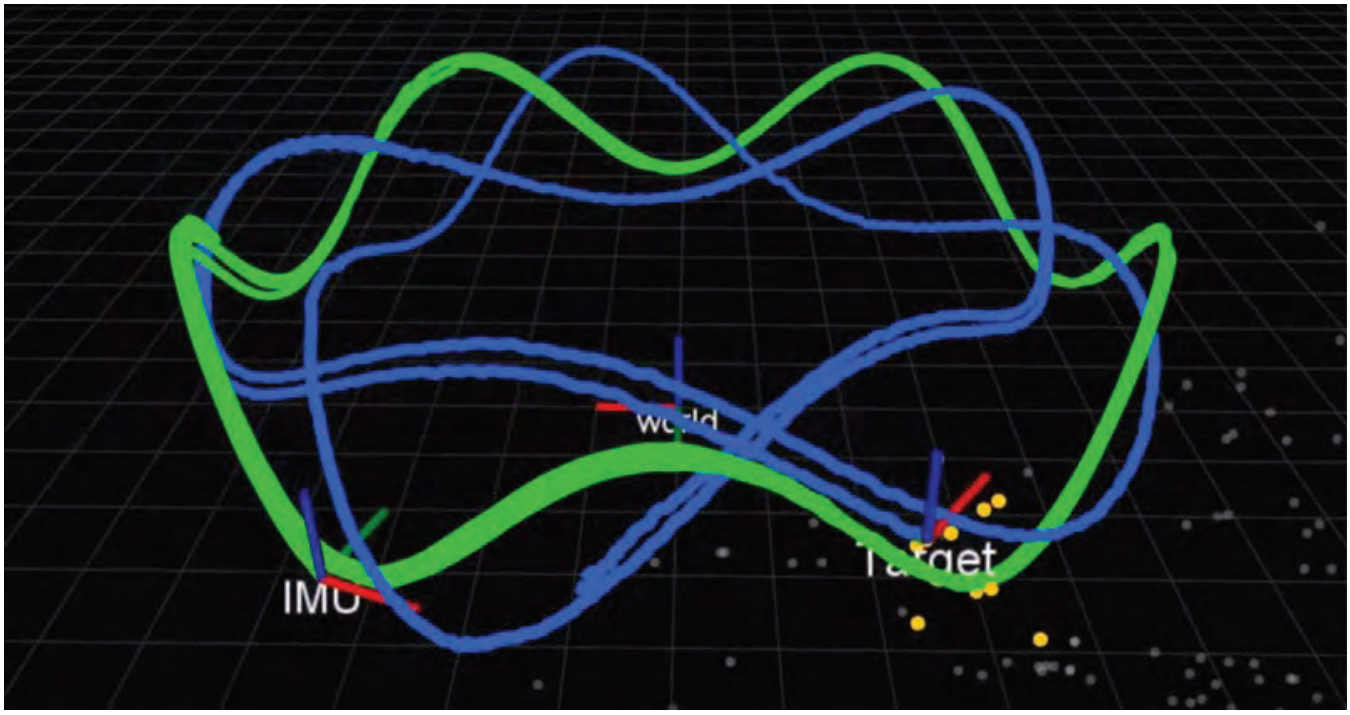
Kun (Kelvin) Fu, an assistant professor of mechanical engineering at the University of Delaware, has used a 3D printer to make pure carbon nanotube (CNT) architectures. Fu is believed to be the first person to make these lightweight, strong, highly porous CNT structures using a 3D printer.

Fu's creations could be useful in the manufacture of composites. Carbon nanotubes can add strength to polymer composites. They are also electrically conductive and chemically stable, opening up a world of creative opportunity for use of this material in batteries and electronics, water purification and desalination technologies, tissue-engineered medical implants, and more. "We can print a series of 3D complex structures using carbon nanotubes. This is a pure CNT structure and no binder or polymer is needed." said Fu, "According to literature, no one can do this."

It is difficult to make high-density carbon nanotube inks concentrated enough to flow through a 3D printer and form 3D structures, but Fu developed a novel and completely different technique. Using a unique 3D printing technique developed recently in Fu's lab, Fu printed a variety of complex CNT 3D structures, including tiny replicas of the Eiffel Tower and the Great Wall of China, a small pig's face, a honeycomb, and a UD logo. Each one measures just a few centimeters wide and is strong but lightweight. The structures can sit on top of a dandelion that has gone to seed without crushing the fragile white seeds.

Fu shared how he did it at the IMECE International Mechanical Engineering Congress & Exposition in November 2019.

"This is quite an exciting discovery as it opens up applications in developing miniature and intricate sensors, serving as complex catalyst supports and also in biomedical applications where the focus will be to grow cells or use them as 3D designed scaffolds," said Suresh Advani, George W. Laird Professor of Mechanical Engineering and associate director of UD's renowned Center for Composite Materials.



GIVING SMART VEHICLES THEIR SENSE OF DIRECTION

Scientists around the world are racing to develop self-driving vehicles, but a few key components have yet to be perfected. One is localization — the vehicle's ability to determine its place and motion. Another is mapping — the vehicles' ability to model its surroundings so that it can safely transport passengers to the right place.

The question is: How do you give a vehicle a sense of direction? Global positioning satellite (GPS) devices are not available or reliable in all contexts. Instead, many experts are investigating simultaneous localization and mapping, or SLAM, a notoriously difficult problem in the field of robotics. Novel algorithms developed by assistant professor Guoquan (Paul) Huang are bringing the answer closer into view.

Huang uses visual-inertial navigation systems that combine inertial sensors, which contain gyroscopes to determine orientation and accelerometers to determine acceleration, along with cameras. Using data from these relatively inexpensive, widely available components, Huang measures and calculates motion and localization.

In a paper published in *The International Journal of Robotics Research* (IJRR), Huang and his team found a better, more accurate solution for combining the inertial measurements. Until now, scientists used discrete integration to approximate the solution. Instead, Huang's group found a solution and proved that it was better than existing methods. Even better, they are sharing it.

"We open source our code. It is on GitHub," said Huang. "Many people have used our code for their systems." In another recent IJRR paper, Huang and his team reformulated the SLAM problem as a formula that computes small increments of motion by the robots equipped with the visual and inertial sensors. Many of these research videos can be found on Huang's Lab YouTube Channel: https://www.youtube.com/c/rpng-ud.

These discoveries could have applications beyond autonomous vehicles, from cars to aerial drones to underwater vessels and more. Huang's algorithms could also be used to develop augmented reality and virtual reality applications for mobile devices such as smartphones.

In 2018 and again in 2019, Huang received a Google Daydream (AR/VR) Faculty Research Award to support this work.

Find the articles at https://doi.org/10.1177/0278364919835021 and https:doi/10.1177/0278364919853361.

This image shows that the team uses a camera and an inertial measurement unit (IMU) to simultaneously localize a robot and track a moving target. The green line is the robot's trajectory and the blue line is the target's trajectory.

EXPLORING THE INTERSECTION OF COMMUNITIES AND TECHNOLOGY

New research center brings together experts in sociotechnical systems

Pictured from left to right are doctoral student Logan Beaver, Professor Andreas Malikopoulos, Former Secretary of Transportation Anthony Foxx, doctoral student Behdad Chalaki and master's degree student Yiming Wan.

From smart speakers in our living rooms to autonomous vehicles on our roads, society is becoming more and more integrated with technology. The convenience and other benefits of high-tech devices must also be weighed with their drawbacks, such as privacy issues that arise when personal information is shared digitally.

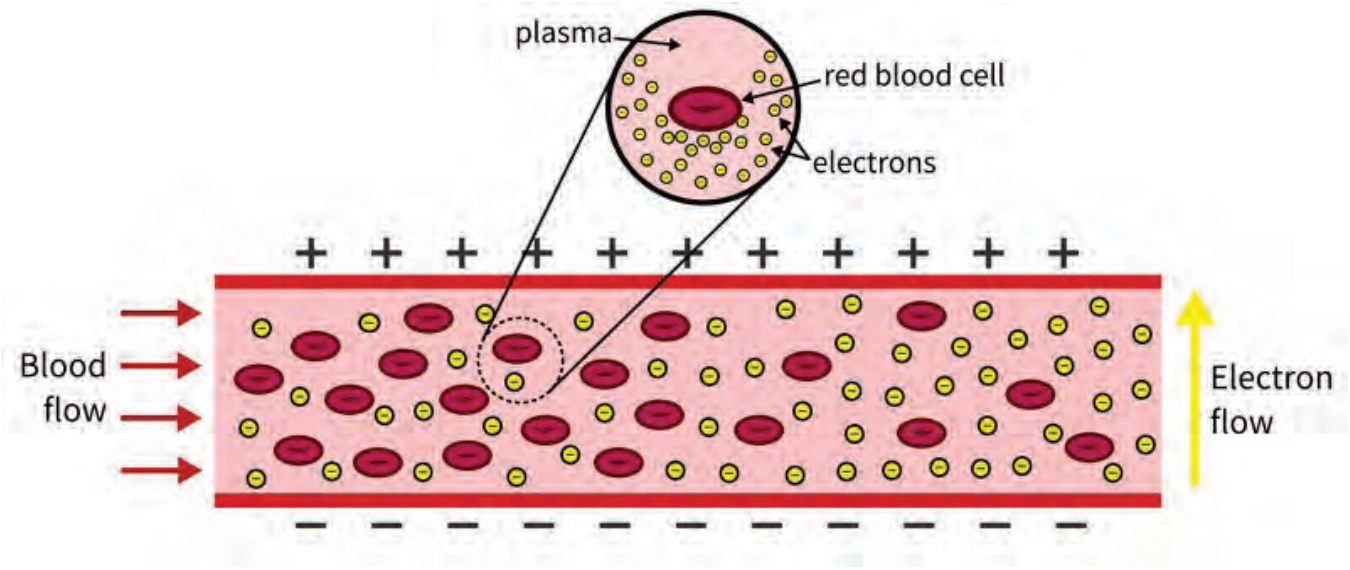
In a new interdisciplinary UD research center, experts aim to use system-based approaches to address complex challenges at the intersection of technological, social, and institutional dimensions.

The Sociotechnical Systems Center (SSC), launched earlier this year, is led by Andreas Malikopoulos, the Terri Connor Kelly and John Kelly Career Development Associate Professor in the Department of Mechanical Engineering.

"Addressing our pressing challenges related to improving quality of life encompasses the interaction of three heterogeneous dimensions: (1) the technological dimension that includes technologies indented to solving problems, (2) the social dimension that addresses the societal impact of these technologies and the implications to human behavior and society, and (3) the institutional dimension that includes the behavior of organized units such as administrators that govern these technologies through policies," said Malikopoulos.

The constellation of these dimensions constitutes a sociotechnical system that should be analyzed holistically, he said, and SSC aims to develop rigorous, system-based approaches aimed at addressing current challenges founded at the intersection of technological, social, and institutional dimensions.

SSC research applies to energy-efficient mobility systems, cybersecurity, human-machine interaction, rehabilitation, autonomous systems, social networks, connected communities, governing and administration, energy-renewable resources, vehicle-to-grid technologies, smart infrastructure and smart materials.



This diagram depicts the way conductivity will change as blood cells break. The yellow dots represent electrons. The red circles represent blood cells. Viewing the graphic from left to right, one can see that when more blood cells are present, fewer electrons are able to get across. As blood cells break, there are fewer barriers and the blood becomes more conductive, making it easier for electrons to move from one side to the other.

MEASURING BLOOD DAMAGE

New ME professor uses mechanical resistance to detect damage to red blood cells

According to the National Kidney Foundation, more than 37 million people live with kidney disease. The kidneys remove waste products to filter blood. For people with kidney disease, dialysis can help by cleaning blood.

However, red blood cells sometimes rupture when blood is sent through a faulty dialysis machine, and there is no reliable indicator that this is happening in a clinical setting until an individual begins showing symptoms.

Now, UD assistant professor of mechanical engineering Tyler Van Buren and collaborators at Princeton University developed a method to monitor blood damage in real-time. They reported their technique in *Scientific Reports*, a Nature publication.

Detecting blood cell damage

In the body, red blood cells float in plasma that is naturally conductive. Red blood cells are chock-full of hemoglobin, an oxygen-transporting protein, that also is conductive. This hemoglobin is typically insulated from the body by the cell lining. But as red blood cells rupture, hemoglobin is released into the bloodstream, causing the blood to become more conductive.

In dialysis, a patient's blood is removed from the body, cleaned, then recirculated into the body. The researchers developed a simple experiment to see if they could measure the blood's mechanical resistance outside of the body. They circulated healthy blood through the laboratory system and gradually introduced damaged blood and saw a direct correlation between the conductivity of the fluid in the system and the amount of damaged blood included in the sample.

While this issue of damaged blood is very rare, the research team's method introduces one potential way to indirectly monitor blood damage in the body during dialysis.

The researchers theorize that if clinicians were able to monitor the resistance of a patient's blood going into a dialysis machine and coming out, and they saw a major change in resistance — or conductivity — there is good reason to believe the blood is being damaged. Read more at https://doi.org/10.1038/s41598-020-62041-8

ROBOTICS ON THE RISE

Center for Autonomous and Robotic Systems to galvanize robotics research at UD

Bert Tanner, a professor of mechanical engineering, leads the new Center for Autonomous and Robotic Systems.

The University of Delaware is becoming a leading destination for cutting-edge robotics and autonomy research, thanks in part to the new Center for Autonomous and Robotic Systems (CARS), which launched in 2020.

Experts in the new center are studying robotics, systems and control and artificial intelligence, with an emphasis on healthcare and environmental applications. They are also studying the ethical, legal and societal impacts of their work.

Led by Bert Tanner, a professor of mechanical engineering, the research center establishes a focal point for robotics research at UD and promotes collaborative, interdisciplinary work among the university's already robust network of robotics and systems experts. Faculty and students at UD are studying robotics for use in environmental monitoring, rehabilitation, agriculture, smart vehicles and much more.

"Over time, we developed collectively a tremendous potential for impact on the field, but we were dispersed around campus, and interdisciplinary collaboration was happening organically, but through personal relationships and networks," said Tanner. "The intention of the center is to provide a platform and a set of resources to nourish such interactions, allow them to grow, and increase their reach and visibility."

The CARS center has already received its first grants, through federal programs such as U.S. Army's Scalable, Adaptive and Resilient Autonomy (SARA), NSF's Smart and Connected Health (SCH), and NSF's Major Research Instrumentation (MRI).

UD STUDENTS IMPLEMENT PROJECTS IN NEWARK AND THE PHILIPPINES

If you judged the organization by its title, you might expect the University of Delaware's Chapter of Engineers Without Borders (EWB) to work exclusively abroad, but they make an impact on the local community, too.

In Newark, participants partnered with the University's Early Learning Center (ELC) to begin a re-design of its outdoor learning environment.

After collaborating on a master plan for the playground last year with the Departments of Landscape Architectureand Early Childhood Education, the project team kick-started their efforts by building two stages, where students can star in their own performances or seek a quiet, shaded break. The stages, measuring 13 by 18 feet and 20 by 13 feet, respectively, are engineered from nearly 40 plastic pallets.

In 2019, nearly 9,000 miles away from Newark in a small Filipino community called Ubujan, a team of EWB students also began construction on a gravity-fed chlorination and distribution system. The realization of nearly four years of work, the system will provide clean, reliable water to more than 1,000 people.

The team also worked with an interpreter to conduct rainwater surveys among members of the local community. The system's design utilized existing resources, including a reservoir and borehole well.

"Our goal was to purify the water by killing any fecal coliform or waste," said Olivia Powell, a 2019 graduate who earned an Honors degree with distinction in mechanical engineering. "We're pumping water up from the borehole well into a shed and

UD students utilized warehouse space at 1743 Holdings LLC, to prepare two pallet stages for the University's Early Learning Center. From left to right are Omar Abdullah, Lucas Attia, Jeffrey Spencer, Phoebe Dowden, George Wieber and Logan Kim.

chlorination system that we built. Here, the water is cleaned and then pumped again into the reservoir to await distribution."

The system is gravity-fed so that water flows in downward-sloping pipes from the outlet of the reservoir to four communal taps placed in various housing clusters.

In partnership with the Ubujan Water Council, the students identified and trained individuals who could keep the system up and running.

Whether near or far, students agreed that their participation in Engineers Without Borders has impacted their time at UD and their future.

"The connection to the community, the amazing mentorship we receive and the friendships I built have kept me going," Powell said. "EWB has given me motivation during my most challenging engineering courses and has made my work fulfilling. It was important, especially as things got tougher."

TEACHING WITH BIRDHOUSES

Early childhood education and engineering majors collaborate to build bird nesting boxes

On a chilly morning at the University of Delaware's Children's Campus, a few dozen children — guided by undergraduates — took hold of screwdrivers to build nesting boxes for local native birds.

Sponsored by the College of Education and Human Development and the College of Engineering, the project is part of a nationwide monitoring program called NestWatch, which crowdsources information about bird reproduction — including nesting dates, number of eggs laid, hatched and how many hatchlings survive — to better understand how bird populations are changing over time as a result of climate change and loss of natural habitats due to urban sprawl.

To prepare for the project, 33 early childhood education majors attended workshops in the mechanical engineering Design Studio with associate professor Jenni Buckley, teaching assistants Erin Rezich and Pete VanderKley, as well as Design Studio co-director Whitney Sample, who trained them on basic hand and power tool operation and then worked with them directly to create the bird houses.

A child works on a birdhouse as part of a program in which College of Education and Human Development students and faculty collaborate with College of Engineering students and faculty to help children learn about birds.

ME STUDENT STARTS SERVICE ORGANIZATION

Jaeah Yoo, Mechanical Engineering, Class of 2021, started a registered student organization (RSO), People for Puerto Rico (PPR).

"I started the club shortly after my experience in Ignite! as a Delaware Innovation Fellows Student," said Jaeah. Ignite! is the early move-in program for Entrepreneurship & Technology Innovation majors as well as for members of the Delaware Innovation Fellows. The program helps students build connections and comfort on campus before the academic work begins.

"At Ignite!, I was exposed to entrepreneurship and the biggest thing I learned was the value of finding a problem," said Jaeah. "It's the first step in the entrepreneurial process; you need it before you can build anything, you can't just make a product and hope that people want it. You need to find a problem, validate it and work on the pain points."

The student was committed to finding a problem to explore and after following the story of Puerto Rico's hurricane disaster, decided it was time to jump into action.

"It blew my mind how quickly and normally Texas seemed to be able to recover from the disaster compared to Puerto Rico," said Jaeah. "I had always wanted to do some sort of service trip, actually help people with my feet on the ground, doing hands-on work and seeing the impact in the people I was helping. Being surrounded by and involved in the Horn Entrepreneurship community, I really learned that change is down to you to get out and do it."

Jaeah started the RSO of People for Puerto Rico with seven founding members in the fall of 2017. The end goal was to organize a service trip to Puerto Rico to help the disaster relief efforts.

"Creating the club helped me get on my way to accomplishing some of my biggest goals," said Jaeah. "I would be able to impact people through service while experiencing a vast new field of recovery work that would let me look for industry problems. I also thought the club would be a great way to create meaningful relationships and memories with other students on campus."

ME ALUMNA RECEIVES FULBRIGHT AWARD

Leah Putman graduated from UD in 2011 with a bachelor's degree in mechanical engineering and a minor in biomedical engineering. Since then, she's worked with W.L. Gore Associates and, most recently, as the Technical Director for Sustainable Health Enterprises in Rwanda. Next year, Putman will embark on a new journey — a master's degree in strategic product development in the Netherlands — with the help of a Fulbright Study Award.

"Over the course of my engineering career, I've seen that my interests really lie in choosing and leading projects for appropriate product development. Of course, 'appropriate' can have a myriad of meanings based on the context of the market, company and user," she said. "I came across Delft University of Technology and knew their program will help me develop the skills to navigate through the design process."

Putman said that the Fulbright award will help her grow personally and professionally. "I tend to be introverted; however, the excitement, challenge and newness of complete unfamiliarity makes me want and need to engage with people and activities. When everything is outside your comfort zone, you create a new one. I'm excited to do that again."

A CELEBRATION FOR TSU-WEI CHOU

Professor honored for 50 years of service to the University of Delaware

When Tsu-Wei Chou, the longest-serving professor in the Department of Mechanical Engineering, was asked how he wanted to celebrate his 50th anniversary at the University of Delaware, he requested a symposium about the past and future of composite materials—the materials that have become his life's work.

In the field of composite materials, Chou is a top scholar, with over 390 journal articles and book chapters and two books published, editor positions at the international journal Composites Science and Technology, and a lengthy list of awards and honors. He co-founded UD's renowned Center for Composite Materials (CCM) 45 years ago.

On October 18, 2019, dozens of faculty members, colleagues, friends and more attended a symposium at the University of Delaware's STAR Tower Audion in honor of Chou, the Unidel Pierre S. DuPont Chair of Engineering. The symposium began with remarks from Ajay Prasad, Chair of the Department of Mechanical Engineering, and Levi Thompson, Dean of the College of Engineering. Suresh Advani, George W. Laird Professor of Mechanical Engineering served as the moderator for the symposium.

"As a teacher, there is no greater satisfaction or source of pride than seeing your students grow to emulate you and the best that you demonstrated," said Thompson. "For 50 years, Tsu-Wei has taught, mentored and supervised countless students who are now thriving as university faculty and industry leaders."

Several of those former students and post-docs attended the Oct. 18 event, including one of the symposium's featured speakers: Amanda Wu, Research Scientist in the Material Science Division at Lawrence Livermore National Lab. The featured speakers also included Karl Schulte, Professor and Former Head of Institute of Polymers and Composites of Hamburg University of Technology in Germany; Michael Wisnom, Professor of Aerospace Structures and Director of Advanced Composites Center for Innovation and Science at the UK's University of Bristol; and Brian Wardle, Professor of Aeronautics and Astronautics and Raymond L. Bisplinghoff Faculty Fellow at the Massachusetts Institute of Technology.

ANDREAS MALIKOPOULOS HONORED

Intelligent Transportation Systems Society gives engineering professor Young Researcher Award

Andreas Malikopoulos, the Terri Connor Kelly and John Kelly Career Development Associate Professor, received the 2019 IEEE Intelligent Transportation Systems Young Researcher Award.

The award recognizes early career contributions and leadership in research and/or application in intelligent transportation systems and related fields.

Malikopoulos received a diploma from the National Technical University of Athens, Greece, and his master's and doctoral degrees from the University of Michigan, Ann Arbor, all in mechanical engineering.

His research interests span several fields, including analysis, optimization, and control of cyber-physical systems; decentralized stochastic systems, stochastic scheduling, and resource allocation. The emphasis is on applications related to connected and automated vehicles (CAVs), smart cities, and sociotechnical systems.

Upon joining the Department of Mechanical Engineering at UD, Malikopoulos established the Information and Decision Science Lab with the vision to advance the analysis, optimization, and control of state-of-the-art cyber-physical networks. His research at UD focuses on applications related to emerging mobility systems and sociotechnical systems. He has made seminal contributions on the technological dimension of mobility systems by developing control algorithms for optimal coordination of CAVs and identifying potential research paths with connected autonomous systems. To help the research community visualize the implications of energy-efficient mobility systems, he created a unique testbed, UD's Scaled Smart City, which includes 35 robotic cars and 10 drones that can replicate real-world traffic scenarios in a small and controlled environment. This testbed can help prove concepts beyond the simulation level and understand the implications of errors/delays in V2V and V2I communication as well as their impact on energy usage.

ALUMNI SPOTLIGHT: NANCY SOTTOS *BME '86, PHD, '91*

Self-healing materials innovator recognized for her influence

Engineers have developed materials with the ability to heal themselves from damage by closing up tiny cracks before they become deep fissures. These materials can be used to protect infrastructure, military equipment, industrial machinery and more.

One of the pioneers behind the development of these self-healing materials is Nancy Sottos, a University of Delaware alumna.

For her impact and influence as an engineer, Sottos, the Department Head, Professor and Swanlund Chair of Materials Science and Engineering at the University of Illinois at Urbana-Champaign, was recently named a member of the National Academy of Engineering (NAE).

Sottos received a bachelor's degree and doctoral degree in mechanical engineering from UD in 1986 and 1991, respectively. She received the Department of Mechanical Engineering's Distinguished Alumni Award in 2007.

"While at UD, one of the most important things I learned for my future career was how to work a part of a collaborative team," said Sottos. "All of my current research is part of a collaboration with chemists, materials scientists and aerospace engineers. UD also gave me a strong foundation in mechanics and materials."

Sottos conducts research centered on polymers and composite materials capable of self-healing and regeneration, mechanochemically active polymers, and materials designed for reliable energy storage. With her collaborators, Sottos co-founded a company, Autonomic Material Inc., that has commercialized self-healing coatings and paints based on their research.

"Future applications may involve composite structures that can self-heal or self-report damage—for example—a space structure that can autonomously heal damage from the environment," she said. "Use of self-healing strategies in solid state batteries is another promising application."

Sottos has previously been recognized with accolades such as the Office of Naval Research Young Investigator Award, Scientific American's SciAm 50 Award, and the Heténi Best Paper Award in Experimental Mechanics.

ME SENIOR WINS UD'S TAYLOR AWARD

UD Alumni Association honors two seniors for academic achievement and community service

The University of Delaware Alumni Association (UDAA) announced that mechanical engineering student Arnav Prasad is the 2020 recipient of the Alexander J. Taylor Sr. Outstanding Senior Awards. His name will be inscribed on a wall in the new Alumni Circle, which honors recipients of the senior awards as well as alumni volunteers and leaders who have made significant impacts at the University.

The Taylor Award annually celebrates a man of the senior class. Recipients demonstrate leadership, academic success and community service. Students must also have a cumulative grade point average of 3.5 or better at the end of the first semester of his or her senior year.

Arnav N. Prasad graduated in 2020 with an Honors degree in mechanical engineering and a minor in mathematics. In addition to his demonstrated ability to problem-solve and think analytically, Prasad has held numerous leadership roles, served as a mentor and has continuously looked for ways to give back to UD and the larger STEM community.

Prasad has served as a teaching assistant for the Mechanical Engineering Design Studio since his sophomore year, instructing peers in using rapid manufacturing technologies that are used extensively in the industry. As a junior, he was selected as an undergraduate TA for two mechanical engineering core courses. He also is president of the American Society of Mechanical Engineers (ASME) at UD, for which he provides peers with unique opportunities to develop their professional and technical skills and has led UD's chapter to two different ASME national robotics competitions.

He also offers his time to volunteer in several capacities both on and off campus. On campus, Prasad participates in many Admissions events, such as Decision Days and Blue and Gold Days, to share his experience as a student at UD with prospective students and their families. As Eugene duPont Distinguished Scholar, he has volunteered each year to plan and coordinate the competition weekend for the next class of Scholars, composed of over 90 high school students. "UD has played an invaluable role in shaping me as a young professional, and I am proud to pay it forward," Prasad said.

Outside the UD campus community, Prasad spends 15 hours each week mentoring a FIRST Robotics team based in Wilmington. Many of the groups he mentors are from underrepresented populations.

"My own participation on this team during high school played a vital role in my decision to pursue a mechanical engineering degree," he said. "Now, as a team mentor, I am able to ignite in my students the same passion I have for knowledge while inspiring them to face challenges with an open mind."

Prasad is pursuing graduate courses at UD through the 4+1 Bachelor of Mechanical Engineering/Master of Science in Mechanical Engineering program.

"As my [undergraduate] time at UD comes to a close, I reflect gratefully on the skills and experiences I have acquired and look enthusiastically to future opportunities to implement all that I have learned. Thank you, UD."

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