Autumn 2024

MESSENGER

MECHANICAL ENGINEERING | UNIVERSITY *of* WASHINGTON

Improving cancer surgery outcomes, pages 6-7

CHAIR'S MESSAGE

Our students, faculty and alumni continue to have important impacts in making the world a better place, from developing innovative materials and researching sports injuries to scaling up battery manufacturing and advancing health care.

I want to acknowledge Professor Jonathan Liu, who has received an up to $21.1 million award to develop his lab's 3D imaging and AI technologies to assist surgeons so they can remove cancers more accurately and rapidly. He is leading a team that includes Alpenglow Biosciences Inc., Harvard Medical School, UW Medicine and Vanderbilt University Medical Center to help improve outcomes for people affected by cancer. You can read more about it in this issue.

A commitment to solving real-world challenges is one reason why our department continues to draw a growing number of students each year. This fall, we welcomed ME's largest junior and senior classes yet and expanded our spots for first-year students to 180, while reserving seats for our excellent community college transfers. I am excited to see these students go into the world and to learn how they use their engineering education to transform our lives for the better.

Alberto Aliseda
Mechanical Engineering Chair
PACCAR Endowed Professor

REMEMBERING FACULTY

Professor Emeritus Philip Malte is remembered for his notable research on energy and environmental combustion. Highlights include designing and applying renewable energy systems for the National Parks and the Puget Sound region, as well as studies on wood combustion and thermo-chemical conversion. He was the founding director of what is now the Pacific Marine Energy Center at the UW. Malte was a fellow of the American Society of Mechanical Engineers and led the Lab for Energy and Environmental Combustion. He passed away in March 2024.

In his 62-year career at the UW, **Professor Emeritus Ashley Emery** had a significant impact on the ME department. Emery served as ME chair, associate dean of the College of Engineering, president of the UW Faculty Senate, National Science Foundation program manager, Puget Sound Engineer of the Year, and chief editor for the American Society of Mechanical Engineers (ASME) Validation and Uncertainty Quantification. He was elected to the ASME and made research contributions in heat transfer, scientific computing and other subfields. He retired in 2024 and passed away in the spring.

ALUMNI AWARD

The late **Frank Robinson** (BSME '57), who founded the Robinson Helicopter Company in 1973, will be inducted into the National Aviation Hall of Fame for his lasting contributions to aerospace. Robinson is remembered for the design, certification and manufacture of the R22, R44 and R66 one- and two-seater personal helicopters. He was a dedicated supporter of UW students and, in particular, of ME. He established scholarships to help engineering students from Whidbey Island attend the UW, and his family has continued his legacy by supporting the Interdisciplinary Engineering Building, set to open in 2025.

ME EXTERNAL ADVISORY BOARD

Thanks to the following alumni and friends for participating on the 2023-24 board:

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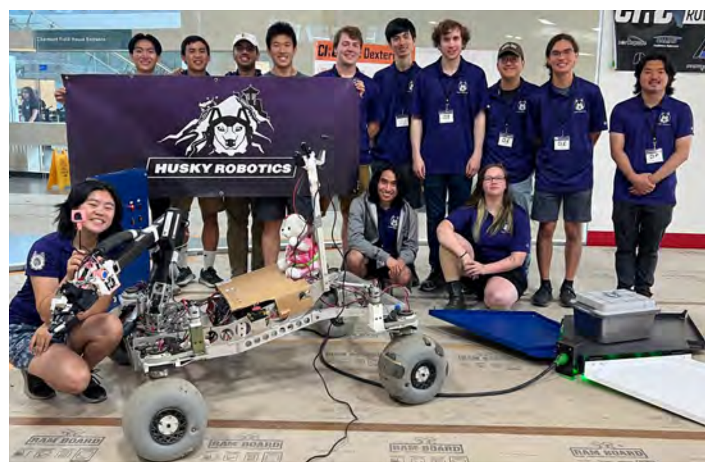
Student club updates

The **Advanced Robotics at the UW** student organization (right)—which builds robot fleets to face off against other universities—was named the RoboMaster North American Champion in June 2024. Competing in Colorado against 25 teams from across the globe, the team won 1v1 and 3v3 confrontations.

The **Husky Robotics** team (below), which designs and builds a mock Mars rover each year, won third place in the 2024 Canadian International Rover Challenge. The team also earned first place in a task demonstrating exceptional arm dexterity and precision.

Out of 75 teams, **UW Formula Motorsports** (above) was awarded fastest lap and seventh place overall at the Michigan Formula Society of Automotive Engineers (SAE) competition. The team competed with their T35 electric race car in both static and dynamic events.



Washington Superbike (left) is in the design-to-manufacturing phase for the team's third-generation zero-emission electric motorcycle. The club displayed their bike during last spring's Engineering Discovery Days.

E-Truck is converting a medium-duty truck into a battery electric vehicle. Last spring, the team showcased their truck during Engineering Discovery Days. Since then the team has been upgrading softwares and planning for a high-voltage storage and bench testing area.

Powering small electronics with body heat

What if in the future, wearable devices such as fitness trackers could use body heat to power itself?

By Sarah McQuate
Photo by Kiyomi Taguchi

ME researchers developed a flexible, durable electronic prototype that can harvest energy from body heat and turn it into electricity that can be used to power small electronics, such as batteries, sensors or LEDs. This resilient device still functions even after being pierced several times and then stretched 2,000 times.

"I had this vision a long time ago," says ME Assistant Professor Mohammad Malakooti. "When you put this device on your skin, it uses your body heat to directly power an LED. As soon as you put the device on, the LED lights up. This wasn't possible before."

Traditionally, devices that use heat to generate electricity are rigid and brittle, but Malakooti and his team previously created one that is highly flexible and soft so that it can conform to the shape of someone's arm.

ME Assistant Professor Mohammad Malakooti demonstrates the wearable device his lab created that can harvest energy from body heat to power small electronics.

This device was designed from scratch. The researchers started with simulations to determine the best combination of materials and device structures and then created almost all the components in Malakooti's iMatter lab.

At the prototype's center are rigid thermoelectric semiconductors that convert heat to electricity. These semiconductors are surrounded by 3D-printed composites with low thermal conductivity, which enhances energy conversion and reduces the device's weight. To provide stretchability, conductivity and electrical self-healing, the semiconductors are connected with printed liquid metal traces. Additionally, liquid metal droplets are embedded in the outer layers to improve heat transfer to the semiconductors and maintain flexibility.

In addition to wearables, these devices could be useful in other applications, Malakooti says. One idea involves using these devices with electronics that get hot.

"You can imagine sticking these onto warm electronics and using that excess heat to power small sensors," Malakooti says. "This could be especially helpful in data centers, where servers and computing equipment consume substantial electricity and generate heat, requiring even more electricity to keep them cool. Our devices can capture that heat and repurpose it to power temperature and humidity sensors."

These devices also work in reverse, in that adding electricity allows them to heat or cool surfaces, which opens up another avenue for applications.

"For now, we're starting with wearables that are efficient, durable and provide temperature feedback," Malakooti says.

ME Ph.D. candidate Youngshang Han and former ME postdoctoral scholar Halil Tetik were also involved in the research. This research was funded by the National Science Foundation, Meta and The Boeing Company. ■

See how the device works in this video.

Understanding women's sports injuries

ME Assistant Professor Jenny Robinson studies differences between how male and female tissues recover after sports injuries.

Photo by Katherine B. Turner/University of Washington

The ACL is a ligament that helps stabilize the knee. ACL tears are two to eight times more common for women than for men in the same sports. Robinson is interested in designing better methods to help female athletes train to prevent and recover from injuries.

Here, Robinson, who is also the endowed chair in women's sports medicine and lifetime fitness in the orthopaedics and sports medicine department at UW Medicine, discusses common injuries for female athletes and how her research team is working to address them.

Why do ACL tears happen? How are they treated?

ACL tears are extremely common in activities that require cutting, pivoting, quick turns of directions (high strain rate) and/or high-contact sports. We see this injury often in sports such as soccer, basketball, rugby, downhill skiing and football.

If the ACL is completely torn, it needs to be reconstructed. One method involves grafting a tendon from another part of the body. For example, using patellar or hamstring tendons are some of the most common options. But this can lead to additional risk for injury at the donor site. Sometimes the reconstructions are torn again, which requires revision surgery. Any subsequent injuries and/or post-traumatic osteoarthritis can make this career ending.

Why is it more common for women to tear ACLs?

There are many possible reasons including anatomical differences that lead to altered biomechanics, differences in tissue structure and properties, and sex hormone differences, including fluctuations that occur in women during the menstrual cycle.

Why is it important to focus on ACL injury prevention?

If there has ever been a time to invest in ACL injury prevention, it's now. For professional athletes, tracking ACL risk is critical for reducing the likelihood of degenerative conditions after acute injuries. These steps ensure athletes have long careers, livelihood and support for their families. Understanding ACL injury risk is also important for non-professionals, youth athletes, parents and coaches as well. It ensures a lifetime of peak physical and mental health.

How does your research focus on female athletes' recovery from injuries?

My research group is trying to determine what cues lead to tissue scarring versus regeneration so that we can develop processes that inhibit scarring and promote regeneration. How do sex hormones and mechanical cues regulate tissue structure and function? What happens to the cells in these tissues when there are different mechanical or hormonal changes?

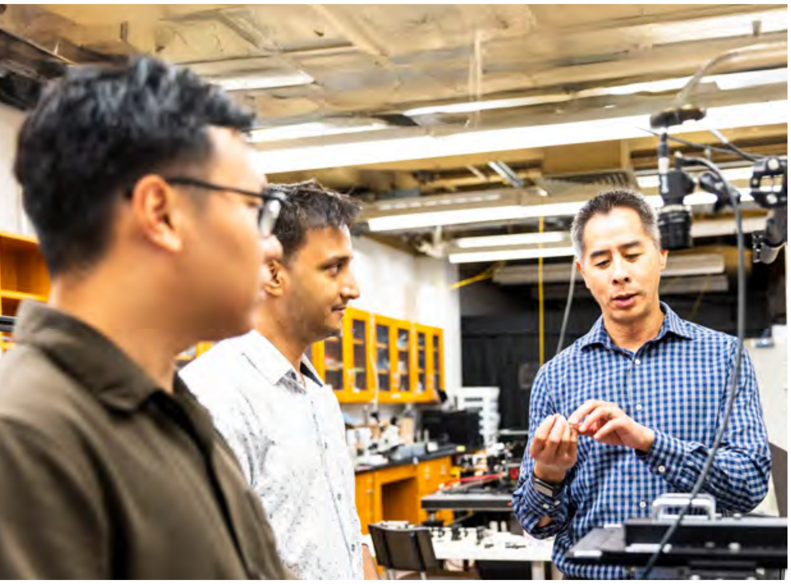
We need this information to be able to design methods that reduce or prevent injury, provide clearer and more patient-specific surgical and therapy recommendations, and develop techniques to promote functional regeneration and reduce scarring. ■

Improving cancer surgery outcomes

A new project will build on and test 3D imaging and AI technologies developed in ME Professor Jonathan Liu's lab to help surgeons remove tumors more precisely and efficiently.

By Lyra Fontaine
Photos by Dennis Wise/University of Washington

Almost 2 million people are diagnosed with cancer in the U.S. each year, and surgical removal is often the first treatment option for solid tumors. However, it's difficult for surgeons to identify the surgical margin, which is the edge of healthy tissue surrounding the tumor, during surgery. If cancer remains present at the margin after the procedure, studies show that their long-term outcomes are generally worse. Patients may also need to undergo additional costly and risky treatments, including additional surgeries to remove the residual tumor.



ME Professor Jonathan Liu, right, with graduate student Rui Wang, left, and research engineer Rauf Kareem, center.

A new multi-university project led by ME Professor Jonathan Liu aims to help surgeons to remove cancer tumors more completely and rapidly during a single procedure. The project will receive up to $21.1 million out of $150 million in awards announced in August from the Advanced Research Projects Agency for Health (ARPA-H). The federal funding is part of the Biden administration's Cancer Moonshot initiative, which aims to reduce the U.S. cancer rate by at least half and improve the experience of people who are affected by cancer.

Building on the technologies developed in Liu's lab, the goal is to develop an intraoperative "flatbed scanner," which would be located in the operating room and used to comprehensively image the margin surfaces of surgical specimens within 15 minutes of their removal. The images will assist surgeons in determining whether the entire tumor was removed, and if not, where they should continue to resect.

"Developing these technologies, which include imaging hardware and AI analysis methods, and validating them well in the clinic requires a large team of investigators, which is difficult to fund with other funding mechanisms," Liu says. "ARPA-H provides the vision, resources and funding to make this type of research possible."

ARPA-H was established in 2022 within the U.S. Department of Health and Human Services to improve the U.S. government's ability to accelerate high-potential, high-impact biomedical and health solutions. The funding agency invests in projects that cannot be easily achieved with standard funding mechanisms, with the aim of leveraging research advances for real-world impact, which aligns with Liu's goals.

"We need to develop and validate our methods within realistic surgical environments in collaboration with a team of clinicians at various sites working on

different forms of cancer," Liu says. "I'm excited about the potential to develop and refine a technology to the point where it can potentially be commercialized and have a real-world impact for surgeons and patients with cancer."

Graduate student Qinghua Han examines images of surgical margin surfaces provided by open-top light-sheet microscopy (OTLS) technologies.

The project includes a collaboration with Alpenglow Biosciences Inc., Harvard Medical School and large-scale clinical studies at UW Medicine and Vanderbilt University Medical Center.

Developing tech to guide surgeons

Preliminary studies have shown that the open-top light-sheet (OTLS) microscopy technologies developed by Liu's lab can, in principle, allow for rapid microscopic imaging of fresh tissue surfaces to guide tumor-resection procedures. Unlike the currently used 2D method for assessing the margin, OTLS can provide a 3D view of the margin surfaces, which could lead to more complete tumor resection and better patient outcomes. The non-destructive approach doesn't require manual tissue preparation and could reduce costs.

However, before it can be useful for surgeons, the technology must be able to image very large specimens at the cellular scale within a short enough time window. These ARPA-H studies are the first time that the 3D imaging and AI technologies developed by Liu's lab will be tested under realistic surgical conditions. The funding also enables the researchers to improve their technologies with the level of automation, speed and accuracy needed for clinical adoption.

Since spatial resolution or magnification trades off severely with imaging speed, the researchers will image the majority of the surgical margin at relatively low resolution and rely on AI algorithms to identify the riskiest "hotspots" to selectively image at higher resolution for accurate diagnosis of residual tumor cells at the margin surfaces. Liu's team will develop multi-resolution AI analysis methods in collaboration with Faisal Mahmood, associate professor of pathology at the Brigham and Women's Hospital of Harvard Medical School.

The research aims to improve surgical guidance for breast cancer and head and neck cancer. At UW Medicine, studies will focus on breast lumpectomy procedures for clinical validation, led by Dr. Sara Javid, professor of surgery at the UW School of Medicine, and Dr. Suzanne Dintzis, professor in laboratory medicine and pathology at the UW School of Medicine. Surgeons at Vanderbilt, Dr. Eben Rosenthal and Dr. Michael Topf, will lead studies focusing on head and neck surgical specimens.

In addition, the project will fund the first research collaboration between Liu and a company he co-founded in 2018, Alpenglow Biosciences Inc. Dr. Nicholas Reder, a clinical instructor at the UW Medicine Department of Laboratory Medicine & Pathology and CEO of Alpenglow, was formerly a pathology resident at the UW as well as a researcher in Liu's lab.

U.S. Senator Patty Murray of Washington weighed in on the news of the award. "The cutting-edge work happening at UW will help doctors get a full, accurate picture of the tumors they are working to treat, so they can make sure patients get the most effective care possible," she said. ■

CAPSTONES ADDRESS INTERDISCIPLINARY CHALLENGES

ME students spend their senior year tackling real-world challenges through interdisciplinary capstone projects. Last year, students developed prototypes for wave-energy converters, improved handcycles, aircraft composite materials and more with support from industry sponsors such as PACCAR and The Boeing Company. Below, we highlight recent projects that showcase the students' innovative solutions.

Laser scribing and drilling system

Students developed a laser system tool for scribing solar cells made from perovskite materials. Laser scribing "scrubs" solar cells to straighten edges and reduce defects, which optimizes the cells' manufacturing and performance. The system that the students created could pattern a larger area than the current system at the Washington Clean Energy Testbeds, the UW's open-access lab for climate tech innovation.

"I was interested in this topic because it involved three lasers with different effects, a motion system and 3D printing," says team member Sky Song. "I learned the importance of communicating with industrial vendors who provided our materials, and taking shipping into account."

MicroFloat drag screen

Another project focused on improving the MicroFloat, a buoyancy-controlled underwater oceanographic sensing device that helps scientists gather data. The float's internal motor actuation can lead to high power consumption and data collection noise. The students created a removable drag screen for the float to reduce the motor actuation while increasing hydrodynamic drag and data accuracy. They found a slight improvement after testing it in a controlled tank and in Lake Washington on a boat.

"I chose this project because of the hands-on mentorship," says Carrie Lin. "It was my first time working with fluidics, which was a learning curve. It was exciting to learn new things."

This project was sponsored by the UW Applied Physics Laboratory.

One project involved developing a prototype for a laser system tool for scribing solar cells made from perovskite materials. Photo by Matt Hagen

An in-home mobility system

Several capstone projects stemmed from the Adaptable House Project, which aims to design an in-home mobility system that could adapt to varying energy levels and abilities. One of the teams designed a harness-based support system attached to an overhead frame structure, with multiple levels of support for people with mobility-based disabilities. The goal was to make

One team created a drag screen for the MicroFloat, a buoyancy-controlled underwater oceanographic sensing device. Photo by Matt Hagen

A team designed a harness-based support system attached to an overhead frame structure. Photo by Jorge Azpeitia/University of Washington

the system safe, durable, aesthetically pleasing and comfortable for long periods of wear.

The team's final prototype was made with cotton blend material with nylon webbing, shoulder padding, 3D-printed plastic to provide structure in the back area and velcro to close the harness. They selected a hammock chair with a footrest and a foam back rest to provide full support for a user if needed. The team found that the frame and harness support up to 300 pounds for all system modes, and users can comfortably wear the system for more than four hours.

"One reason I went into engineering was to tangibly benefit people's lives," says Monica Santiago. "This has been a good way to give back to the community."

Another Adaptable House Project team demonstrated how to implement adaptable body weight and fall protection systems to aid and empower individuals with mobility-based disabilities. "If the user is wearing the harness, the prototype we built can adjust their body weight by taking some weight off them," says team member John Shim.

John Shim demonstrates a prototype of an adaptable body weight and fall protection system. Photo by Matt Hagen

The students built a prototype of a motor that provides rotational energy and a pulley that redirects the rotational power to lift the user. The system has different modes such as "fall protection" and "float," which suspends the user in the air. Eventually, a scaled-up version of this prototype could make it easier for users to move around their homes.

"This project was a perfect fit because I wanted to get involved in the medical industry and help others using technology," says Shim.

ShockSafe

To more accurately distinguish pediatric and adult patients during cardiac arrest emergencies, an Engineering Innovation in Health (EIH) capstone team developed an automated external defibrillator (AED) weight-detection accessory: ShockSafe.

ShockSafe team members at the 2024 EIH Spring Symposium. Photo by Matt Hagen

The students found that using anthropometric data of body measurements and proportions, which they input into a machine learning regression model, was the best approach to determine whether an individual is a child or an adult. They designed ShockSafe with four tabs containing small sensing devices that pull out to measure certain lengths across the patient's body. The measurement is then sent to the attached computer device, which lets the responder know via voice prompting whether to provide a pediatric or adult shock dosage.

"Our device helps responders make a decision about whether to use an AED's pediatric or adult mode based on the weight of the patient," says team member Lily Nordyke. "We are making the decision making process more quantitative."

This project was sponsored by Philips. ■

Sound solutions

UW researchers have developed ultrasound technologies that break up and remove kidney stones.

ME Professor Michael Bailey. Photo by APL-UW

Kidney stones affect about 1 in 10 people, and can cause severe pain. A common way of breaking up kidney stones without surgery, called shock wave lithotripsy, typically requires anesthetics and large equipment. Fragments may remain in the kidney, requiring more treatments. Researchers across the UW — including in ME, the Applied Physics Laboratory (APL) and UW Medicine — have pioneered new treatments using ultrasound-based techniques to break up and remove stones more efficiently.

ME Professor Michael Bailey explains how the UW team started working in this area and how their technology is improving kidney stone treatment for humans and pets.

How did you start researching kidney stones and developing a new treatment?

Our UW team has been part of a 30-year National Institutes of Health (NIH) grant to study how kidney stones are broken. We studied shock wave lithotripsy and recognized some its downsides, such as the need for anesthesia and additional treatments. About 15 years ago, with some NASA funding, we decided to make a better treatment from what we'd learned.

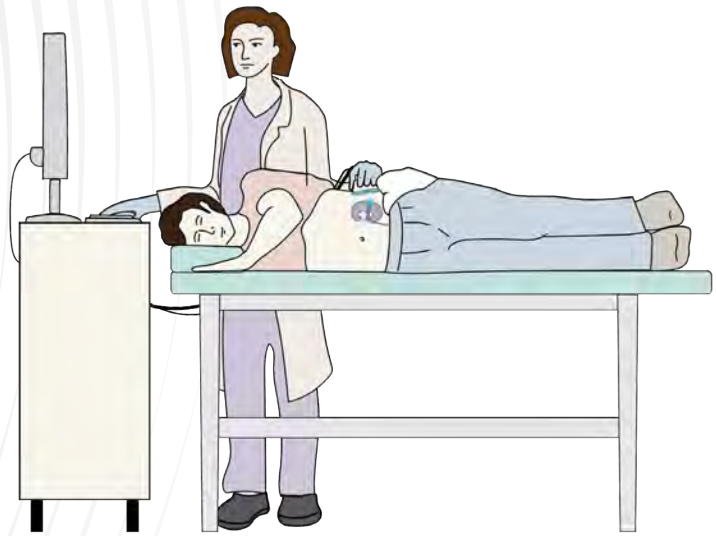
We tried a new approach, called burst wave lithotripsy, which uses lower-amplitude sound waves to break kidney stones. Simultaneously, we invented ultrasonic propulsion to sweep the stones out. We engineered a handheld device, tested it to prove it was safe and effective, got FDA approval to do a study and showed success in a series of clinical trials. The technology is being commercialized by a company SonoMotion that spun out from the UW, and all our data are considered in regulatory review of any future products.

How does the ultrasound technology break and move kidney stones?

Shock wave lithotripsy sends an acoustical impulse, while burst wave lithotripsy applies the same energy in a lower-amplitude, longer-duration tone burst. Burst wave lithotripsy amplifies the stress within the stone, stresses the stone repeatedly within each burst and applies more pulses per second. The locations in the stone are uniformly spaced and therefore create uniformly small fragments that pass with the urine.

With ultrasonic propulsion, we move stone fragments out of the kidney using pulses with even lower

ME Professor Michael Bailey, left, and urology fellow Patrick Samson, right, demonstrate ultrasonic propulsion. Photo by APL-UW amplitude and longer duration. Both burst wave lithotripsy and ultrasonic propulsion use the same machine, which incorporates real-time ultrasound imaging to see the stones move and break. The machine features a handheld probe, which is used on awake patients who often pass the stone fragments themselves before leaving the clinic.



Ultrasonic propulsion moves stone fragments out of the kidney using lower-amplitude, longer-duration pulses while enabling the clinician to view real-time ultrasound imaging. Graphic by APL-UW

What have recent studies about these technologies found?

Our recent NIH-funded randomized controlled trial shows that ultrasonic propulsion offers clinical benefit for kidney stone patients by reducing the number of return visits to the emergency room or urologist. Reducing return visits could potentially lower health-care costs.

Our hope is that eventually, any provider can use burst wave lithotripsy and ultrasonic propulsion treatments — for both humans and animals. Initial results of a recent clinical trial with the University of Minnesota College of Veterinary Medicine on 10 cats with kidney stones show that burst wave lithotripsy could be a safe and effective alternative to surgery. We've also treated a dolphin and a seal.

Many people on our research team are engineers who want to build new medical devices, and we've done that. If you want to see the device you created work for people, it's hard to imagine not being there through every step of the process, including clinical trials and commercialization. ■

Faculty news

Steve Brunton, the Boeing Professor in Mechanical Engineering, was elected a 2024 American Physical Society Fellow. He was recognized for significant research contributions to the modeling and control of fluid dynamics, and for innovative science education.

Jae-Hyun Chung was promoted to Professor, **Sawyer Fuller** was promoted to Associate Professor and **Igor Novosselov** was promoted to Research Professor.

Assistant Professor **Aniruddh Vashisth** received the 2024 Young Composites Researcher Award from the American Society for Composites, which recognizes an early-career member of the composites community whose research has significantly impacted the science and technology of composite materials.

ME will work with the Pacific Northwest National Laboratory on research funded by the U.S. Department of Energy Advanced Materials and Manufacturing Technologies Office. **Jie Xiao**, Boeing Martin Professor of Mechanical Engineering, will lead a project to develop analysis tools to improve estimates of battery manufacturing costs and timelines. Assistant Professor **Shijing Sun** is co-principal investigator on a project to develop a framework for translational battery manufacturing research testbeds.

The Novosselov Research Group, led by Research Professor **Igor Novosselov**, received a $3.5 million grant from the U.S. Environmental Protection Agency to study the destruction of hydrofluorocarbon refrigerants through alkaline hydrolysis. ■

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Welcome new faculty

Jie Xiao is the Boeing Martin Professor of Mechanical Engineering, with a joint appointment at Pacific Northwest National Laboratory. Xiao's research in fundamentals and applications of energy storage materials and systems has helped accelerate the process of establishing domestic manufacturing capabilities for clean energy technologies. Xiao is the deputy director of the Innovation Center for Battery500 Consortium and has been named in the top one percent of Clarivate Analytics Highly Cited Researchers since 2017.

Juming Tang has a joint appointment as professor in ME and in industrial and systems engineering, where he has been appointed chair. Prior to joining the UW, Tang was a Washington State University Regents Professor and Distinguished Chair of Food Engineering. A pioneer in advancing thermal processing technologies for pathogen control in commercial production of ready-to-eat foods and ingredients, Tang was elected to the National Academy of Engineering for inventing and commercializing electromagnetic spectrum wave-based food processes.

Michelle Hickner joins ME as an assistant teaching professor after receiving her Ph.D. from the department in 2023. As a research engineer with the College of Engineering AI Initiative for Education and Research, she explores data-driven mathematical methods for sensing, control and flight, with a focus on bio-inspired mathematical models. Hickner has served in several UW roles in the past, including supporting the ME composites shop and educational labs.