Spring 2025

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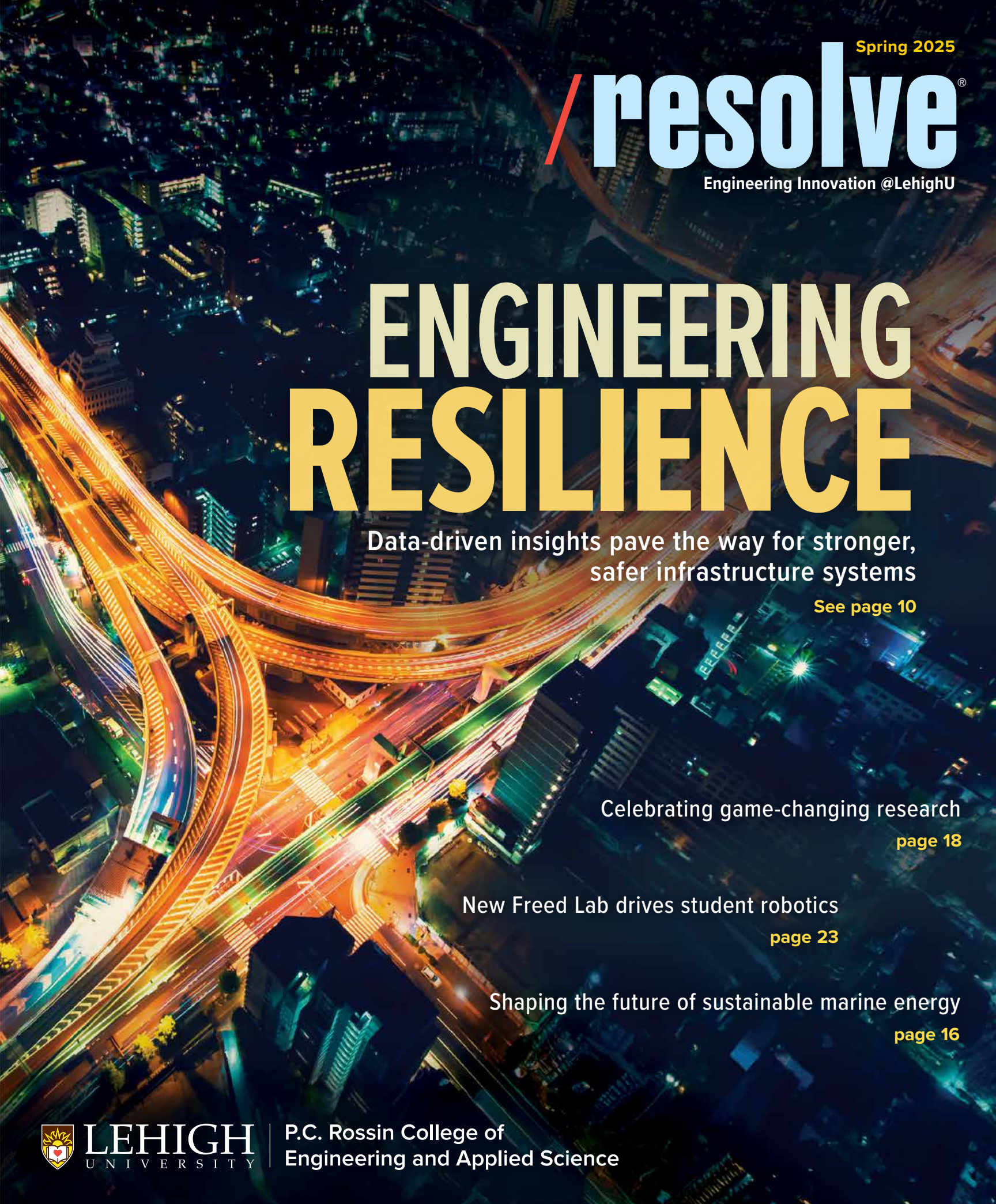
Engineering Innovation @LehighU



ENGINEERING RESILIENCE

Data-driven insights pave the way for stronger, safer infrastructure systems

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Celebrating game-changing research

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New Freed Lab drives student robotics

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Shaping the future of sustainable marine energy

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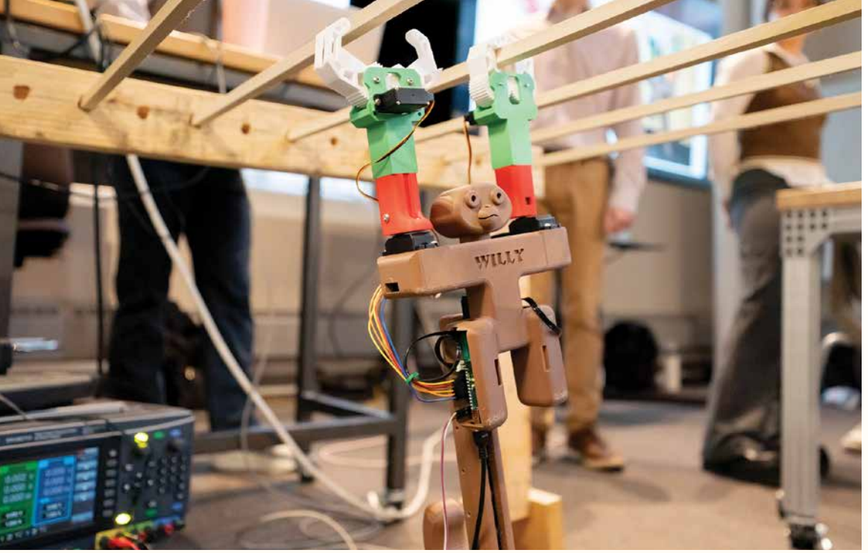
LEHIGH UNIVERSITY | P.C. Rossin College of Engineering and Applied Science



A robotic monkey built for a Senior Capstone Design Project demonstrates *brachiation*—the arm-over-arm movement of primates. "Willy" showcases how Lehigh's Design Labs, including the new Freed Family Robotics Design Studio (page 23), bring ideas to life.

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EDITOR | Katie Kackenmeister

SENIOR WRITER AND MULTIMEDIA CREATOR
Christine Fennessy

DIGITAL DIRECTOR | Marc Rosenberg

DIGITAL MARKETING SPECIALIST
Maegan Anderson

DESIGN | Gipson Studio LLC

CONTRIBUTING WRITERS
Dan Armstrong, Christine Bucher,
Kristen DiPrinzio, Christina Tatu

COVER CREDITS
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P.C. ROSSIN COLLEGE OF ENGINEERING AND APPLIED SCIENCE
Lehigh University
19 Memorial Drive West
Bethlehem, PA 18015
610-758-4025
engineering.lehigh.edu

SUBSCRIBE OR SEND COMMENTS
engineering@lehigh.edu

LEHIGH UNIVERSITY

THIS PAGE: BETH MURPHY; OPPOSITE PAGE: MARCUS SMITH '25

LETTER FROM THE DEAN

Investing in excellence

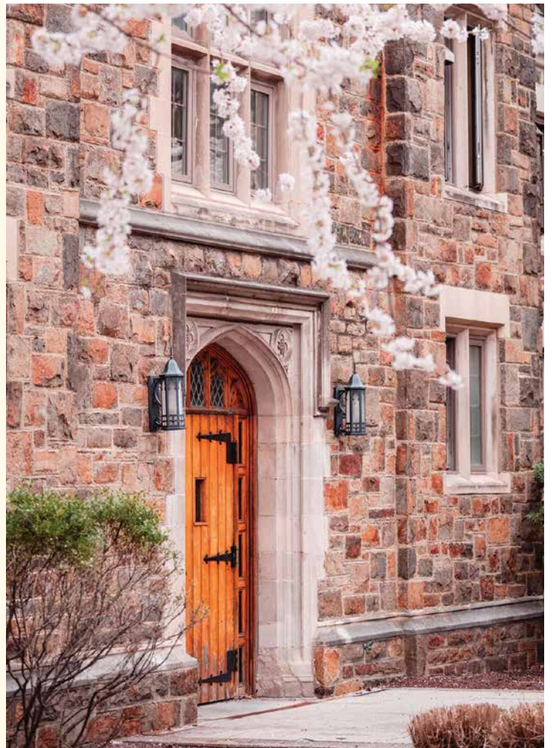
Welcome to the Spring 2025 issue of *Resolve*—a magazine dedicated to research and educational innovation in the P.C. Rossin College of Engineering and Applied Science at Lehigh University.

This issue arrives as ambitious ideas and bold initiatives are taking shape across campus, propelling our academic community forward.

I am honored by the newly established Lewis Hay III '77 '08P '11P and Sherry A. Hay '78 '08P '11P Deanship in the Rossin College. Lew, an electrical engineering alumnus and a former energy executive, is interviewed in the Q&A (page 8).

The Hays' generosity is a transformative investment in the future of engineering at Lehigh. The endowment will provide seed funding for innovative educational programs, enhanced student learning, and faculty recruitment and development—fueling our momentum, advancing cutting-edge research, and empowering outstanding researchers, scholars, and educators. This includes the redesign of the first-year student experience and the people who truly "differentiate a program," as Lew notes in his interview.

That momentum is further reflected in Lehigh's recent achievement of R1 status in the Carnegie Classification of Institutions of Higher Education, the premier level of classification that signifies high research expenditures and graduation of doctoral students. This achievement is a result of Lehigh's strategic focus on research infrastructure, faculty, and PhD programs, activities in which our college has played a vital role.



This elevated classification strengthens our efforts in faculty and student recruitment, research and partnerships, and international collaborations, while raising Lehigh's academic profile.

As you will read in this issue, our research enterprise is indeed thriving, both in established areas of strength, such as infrastructure, and in emerging directions, including marine energy.

Our cover story (page 10) highlights interdisciplinary research using artificial intelligence and advanced data science to enhance the strength and resilience of our infrastructure as it faces climate-driven extreme events and other hazards. And on page 16, we check in with the Atlantic Marine Energy Center (AMEC), a multi-institutional research initiative led by Lehigh and one of only four National Marine Renewable Energy Centers in the United States. AMEC seeks to harness the power of the ocean as a sustainable and clean source of near-limitless energy.

ACHIEVING R1 STATUS IS A RESULT OF LEHIGH'S STRATEGIC FOCUS ON RESEARCH INFRASTRUCTURE, FACULTY, AND PhD PROGRAMS.

This issue's Educational Innovation (page 22) highlights recent expansion in our experiential learning offerings, including a novel mentorship program pairing research-minded undergraduates with doctoral students, as well as a new maker-space focused on robotics, established with support from Lehigh alumnus and trustee Drew Freed '83 '17P and his family.

On page 18, we celebrate national-level accolades for several of our researchers, including associate professor Hannah Dailey, who has received the Presidential Early Career Award for Scientists and Engineers (PECASE), the federal government's top honor for early-career researchers in science and engineering.

Our Rising Star (page 24) is computer scientist Lichao Sun, who is doing fascinating, wide-ranging work with AI to protect intellectual property, support medical decision-making, and evaluate the trustworthiness of the technology itself.

Last, but certainly not least, I am delighted to announce the election of Dan Frangopol, professor emeritus and pioneer in life-cycle civil engineering, to the National Academy of Engineering (page 5). This honor—perhaps the most prestigious recognition accorded to professional engineers—is a testament to his distinguished career. His work exemplifies the innovative spirit and commitment to excellence that define us as an institution.

I hope you enjoy this edition of *Resolve*; thank you as always for your interest in Lehigh Engineering!

Stephen P. DeWeerth, *Professor and Dean*
P.C. Rossin College of Engineering and Applied Science
steve.deweerth@lehigh.edu

Electrical insights into muscle fatigue

Advanced sensors could unlock clues to diagnosing chronic fatigue syndrome and long COVID

Chronic fatigue syndrome (CFS) is a complex and long-term illness characterized by extreme fatigue that doesn't improve with rest, and can worsen with physical activity. The exhaustion is severe enough to limit a person's ability to carry out daily activities like cooking, showering, or even getting dressed. Additional symptoms can include muscle pain, joint pain, memory issues, headaches, sleep problems, and sensitivity to light or sound.

There is no known cause or cure for CFS, which affects an estimated 3.3 million people in the United States, according to the Centers for Disease Control and Prevention.

There's also no specific diagnostic test.

"It's a mysterious disease," says Xuanhong Cheng, a professor of bioengineering and materials science and engineering. "There are no single biological indicators that can be used to diagnose chronic fatigue syndrome, and so doctors are forced to diagnose individuals by ruling out other symptoms and conditions."

Cheng is part of an international team of researchers who recently received funding from the National Institutes of Health to explore molecular- and cellular-level changes in muscle tissue that could potentially lead to better diagnostic tools and therapeutic options for both CFS and related conditions, such as long COVID.

"The symptoms of CFS are very similar to those of long COVID," says Cheng. "But one of the most consistent symptoms across both diseases is muscle pain. Our collaborator [Tiziana Pietrangelo of Università degli Studi "G. d'Annunzio" Chieti-Pescara, in Italy] has studied CFS for more than a decade, and she's found that people with the disease also have elevated oxidative stress in their muscle tissue, which contributes to why the muscle is so easily overworked."

The team is taking a multidisciplinary approach to determine if there are biological indicators within the muscle that could potentially be used to diagnose—and possibly treat—individuals with these conditions.

Pietrangelo will explore the physiology of the skeletal muscle tissue and muscle stem cells, and the role oxidative stress may play in their functions. Stefano Cagnin, a professor at the University of Padova in Italy, will study gene expression in muscle fiber and muscle stem cells, comparing the results of healthy populations with those of people who have chronic fatigue syndrome, to uncover molecular changes linked to the disease.

> "LONG COVID HAS MADE PEOPLE MORE AWARE THAT THESE CFS SYMPTOMS ARE VERY REAL."
>
> —Xuanhong Cheng

Cheng will examine the electrical signature of skeletal muscle stem cells. Using a technology she co-developed called broadband electrical sensing, she will examine characteristics at the cellular level that could reveal if a cell is healthy or diseased.

The team hopes to develop a more comprehensive understanding of how CFS affects muscles and determine whether such changes could be used as diagnostic markers or therapeutic targets. The ultimate goal, says Cheng, is to create non-invasive diagnostic tools.

Additionally, by pinpointing the molecular changes that contribute to the disease, the researchers hope to eventually explore therapeutic strategies, which could, for instance, alleviate oxidative stress and improve patients' symptoms. Such advances are a long way off, but any progress will be welcome for the millions of people who have a disease that has long been misunderstood—and maligned.

"Because CFS has been so poorly understood, the people who have it were sometimes called lazy, or told their symptoms were all in their head," says Cheng. "Long COVID has made people more aware that these symptoms are very real, and they can arise after a viral infection. We're looking forward to helping these people restore their health."

TOP: TUL/ADOBE STOCK; BOTTOM: TATA CHEN/ADOBE STOCK

Supercharging simulations to drive the vision of fusion forward

Mechanical engineering student receives prestigious award to conduct research at DIII-D National Fusion Facility

When it comes to sustainable energy, harnessing nuclear fusion is—for many—a holy grail of sorts. Unlike climate-warming fossil fuels, fusion offers a clean, nearly limitless source of energy by combining light atomic nuclei to form heavier ones, releasing vast amounts of energy in the process.

But it isn't easy replicating and controlling the process that powers the sun.

"We eventually want to move to producing energy this way," says Brian Leard '21, a fifth-year PhD student in mechanical engineering. "But you have to heat the plasma fuel to really, really high temperatures and densities, and then you have to confine it. That's extremely difficult."

As part of the legion of researchers around the world attempting to solve this and other problems associated with turning the vision of nuclear fusion into reality, Leard was recently recognized by the Department of Energy through its prestigious Office of Science Graduate Student Research program. From a large, diverse, and highly competitive field of applicants, DOE selected just 62 students from 24 states to pursue their research at the agency's national laboratories, and ultimately, contribute to addressing the country's energy, environmental, and nuclear challenges. Leard is conducting his research over nine months at the DIII-D National Fusion Facility operated by General Atomics in San Diego.

> "THE ALGORITHM COULD COME UP WITH SOLUTIONS WE AS HUMANS HAD NOT CONSIDERED."
>
> —Brian Leard '21

Together with his team at Lehigh—which is led by Eugenio Schuster, a professor of mechanical engineering and mechanics and Leard's advisor—the PhD student has developed a novel method that integrates advanced neural network models with plasma physics to develop simulation codes that can be used to optimize actuator operation. Such simulation has been done before, says Leard, but the codes currently in use often are very time consuming or neglect certain physical processes that can limit their scope and/or accuracy.

In San Diego, Leard is focusing on conducting optimizations with this improved simulation code by applying different optimization techniques and different couplings between the optimizer and the simulator. Such a model could potentially help reduce the costs of research conducted at tokamaks like DIII-D, and lead to new discoveries.

"Every discharge is hundreds of thousands of dollars," says Leard. "If we can come up with solutions—meaning the right combination of inputs to get to the desired state—by using a simulation code and an optimizer instead of experimentally, we could potentially find improved paths toward advanced operating regimes. The algorithm could come up with solutions that we as humans had not considered."

TOP: MONKEY BUSINESS/ADOBE STOCK; BOTTOM: SHOZIB/ADOBE STOCK

MAPPING MOVEMENT FOR SMARTER, SAFER CITIES

Interdisciplinary team uses advanced algorithms and cross-domain data to predict urban flow

Knowing how people move across urban areas is about more than avoiding traffic jams: "Think about something like COVID-19," says Yu Yang, an assistant professor of computer science and engineering. "Having a better understanding of human mobility could help cities implement transportation policies during times of public health crises, which could reduce infection rates."

Yang recently received a grant from the National Science Foundation to develop a model that can estimate and predict how people move within cities, which could better inform applications ranging from public health policy to transportation and urban planning. The research team includes Lehigh collaborators Lichao Sun, an assistant professor of computer science and engineering, and Yue Yu, a professor of applied mathematics in Lehigh's College of Arts and Sciences.

Currently, cities tend to rely on empirical or historical data to plan for situations—like concerts, games, and severe weather—that significantly impact how people get around. Such an approach, however, is limited because it assumes that past events can predict future mobility patterns.

"And that's a problem," says Yang. "How people got around during a game last year isn't necessarily how they'll get around for a similar event this year. Our research will address this lack of precision and real-time modeling based on interactions between humans and city infrastructures."

Yang and his team will work with New York City and Newark, New Jersey, to collect data from a variety of sources, including cell towers, GPS systems, traffic cameras, subway entry and exit records, and financial transactions (think credit card swipes). Together, the data will provide a more comprehensive look at mobility patterns using cross-domain infrastructure.

In addition to helping cities better plan, design, and control public transportation routes for safer, more efficient services, a unified mobility model could also help city officials detect and react to abnormal patterns of movement caused by large-scale events (festivals and sporting events, for instance) and emergencies (such as hurricanes and floods).

"Human mobility responds to a wide range of variables," says Yang, "which makes this very much an interdisciplinary issue."

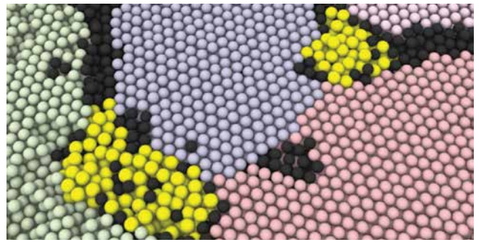
Triple junctions: Innovating where atoms meet

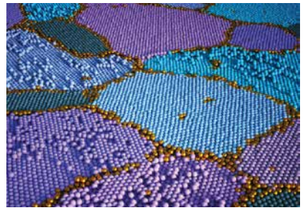
The smallest of spaces hold enormous potential for nanomaterials researchers

How can we engineer materials that are stronger and lighter? What about new materials for extreme conditions such as in jet engines and spacecraft?

The answer, says Fadi Abdeljawad, an associate professor of materials science and engineering, might be hidden in the infinitesimally tiny regions, or boundaries, where atoms in crystals come together.

Along with his collaborators at the Department of Energy's Center for Integrated Nanotechnologies (CINT), Abdeljawad is uncovering how those tiny boundaries have such an enormous impact on the characteristics of nanomaterials.





The images depict enrichment of gold atoms at triple junctions among nanocrystals. A triple junction refers to the point where three different grains within a material meet at the nanoscale.

"Atoms come together to form nanocrystals, which are essentially structures about 1/10,000th the width of a human hair," explains Abdeljawad. "Think of these crystals coming together like pieces of a puzzle, or as tiles on a kitchen floor. Billions of these nanocrystals stack on top of each other to form most engineering materials."

According to the researchers, it is the regions where crystals meet that play an outsized role in determining how a material behaves. In a recent article published in the journal *Nano Letters*, the team explains how tiny features in nanomaterials, known as triple junctions, play a crucial role in maintaining the stability of these materials under high temperatures.

Gold in the corners

Nanocrystalline materials have an extremely fine structure, made up of many tiny crystals. This tiny crystal size can make the material stronger. However, keeping these crystals small and stable over time is challenging because they tend to grow, which can weaken the material.

The researchers in this study discovered that the key to maintaining the stability of these materials at high temperatures lies in triple junctions, corners where three of these nanocrystals meet. (Imagine the corners of three puzzle pieces coming together.)

The scientists found that when certain atoms are added to form an alloy, they prefer to occupy sites at these triple junctions. This "chemical segregation," or gathering of atoms at triple junctions, helps to keep the grains from growing, thereby preventing the material from losing its strength over time.

This specific study demonstrated that gold atoms carefully placed at triple junctions in a platinum nanomaterial allowed the material to remain stable in high-temperature conditions.

"By understanding this process," says Abdeljawad, "scientists can design better nanocrystalline alloys. They can choose specific elements that will go to the triple junctions and stabilize the material. This is particularly important for applications where strength and durability at elevated temperatures are key, such as in the aerospace and energy industries."

Drawing on the power of teamwork

Abdeljawad (pictured, top left, with his students) performed large-scale computational studies that predicted these results. To validate the models, the team partnered with CINT, which provides advanced tools and expertise for nanoscale research, enabling cutting-edge studies in materials science, nanofabrication, and nanophotonics for scientific and technological advancements.

"This is an outstanding example of collaborative science," says Dr. Brad Boyce, a senior scientist at CINT and a study co-author. "Our ideas for how to engineer novel materials by tailoring features at the nanoscale are maturing as a result of the ability to simulate the complex arrangement of atoms that make up these materials."

TOP: SHOTBYASGAR; INSETS: COURTESY OF FADI ABDELJAWAD; RIGHT: MACIEJBLEDOWSKI/ADOBE STOCK

Weeding out plastic pollution in agriculture

Mulch films are widely used in agriculture to suppress weeds, retain soil moisture, and regulate soil temperature, thereby enhancing crop yields. However, conventional plastic mulch films (as pictured below) do not decompose and thus contribute mightily to plastic pollution.

Jonas Baltrusaitis, an associate professor of chemical and biomolecular engineering, is at the forefront of developing sustainable nutrient-delivery materials, including composite nutrient-containing degradable polymers for mulch films.

Recently, this work has earned the support of the United States Department of Agriculture (USDA) and its National Institute of Food and Agriculture through a new multi-year research grant entitled "PARTNERSHIP: Engineering Nutrient-Enhanced Mulch Film to Improve Degradation and Soil Health." Baltrusaitis, the lead researcher, is teaming up with colleagues from the University of Massachusetts Lowell; USDA Agricultural Research Service in Maricopa, Arizona; and Ben Gurion University in Israel, who are contributing diverse and critical expertise to the project.

> "SUSTAINABILITY IS ALSO ABOUT ENSURING ECONOMIC VIABILITY FOR FARMERS."
>
> —Jonas Baltrusaitis

Baltrusaitis' research is focused on creating sustainable nutrient delivery systems by incorporating them into biodegradable polymers that can perform the same functions as traditional plastics, with an ecologically inspired twist. The films would break down naturally and safely, while adding nutrients to the soil to benefit crops.

Baltrusaitis' team is designing nitrogen-efficient materials—urea cocrystals—to provide nutrients to the mulch films. They are collaborating with Margaret Sobkowicz-Kline, a plastics engineering professor at UMass Lowell, leveraging her work with biopolymers such as polylactic acid (PLA) and polyhydroxyalkanoates (PHA), which are derived from renewable resources and can decompose into nontoxic components under specific conditions. Sobkowicz-Kline will combine the cocrystals with commercial bioplastics that are already suited for degradation in soil conditions, but which have unknown impacts on the longer term soil health. Her team will create films with these bioplastic-cocrystal compounds for testing in the laboratory and in agricultural environments.

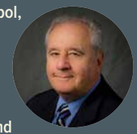
One of the key challenges the team faces is ensuring that the biodegradable mulch films maintain their structural integrity and effectiveness throughout the growing season. To address this, the researchers are investigating various formulations and processing techniques to enhance the durability and performance of the bioplastics. This involves rigorous testing under different soil and climate conditions to ensure that the films meet the practical needs of farmers while decomposing effectively after use.

"We are constantly refining our formulations to strike the right balance between durability and biodegradability," he says. "It's crucial that the films remain effective throughout the crop cycle and then degrade without leaving harmful residues. This requires a deep understanding of both material science and agricultural needs."

In addition to the technical aspects, Baltrusaitis is also focused on the economic viability of such biodegradable mulch films. Traditional plastic films are relatively inexpensive, and transitioning to biodegradable alternatives must be cost-effective for widespread adoption. His team is working on optimizing production processes and sourcing sustainable raw materials to make the biodegradable films competitive in the market.

Baltrusaitis emphasizes the broader implications of his research. "Sustainability in agriculture is not just about protecting the environment; it's also about ensuring economic viability for farmers," he notes. "Our goal is to develop solutions that are affordable and practical, so farmers can adopt them without compromising their livelihoods."

FRANGOPOL ELECTED TO NAE



Dan M. Frangopol, the inaugural Fazlur R. Khan Endowed Chair of Structural Engineering and Architecture, Emeritus, and Professor of Civil Engineering, Emeritus, has been elected to the National Academy of Engineering (NAE) for his pioneering work in life-cycle civil engineering and his leadership in its global development and adoption. Election to NAE membership is among the highest professional recognitions accorded to engineers.

"I am deeply honored and humbled," says Frangopol. "Both the University of Colorado Boulder and Lehigh University have provided great academic environments and colleagues."

NAE membership honors those who have made outstanding contributions to engineering practice, research, or education; the pioneering of new and developing technological fields; major advancement in traditional fields; and/or the development and implementation of innovative approaches to engineering education and leadership. NAE members represent a variety of disciplines and career experiences and are called upon to advise on critical issues affecting the nation and the world.

"Since his arrival at Lehigh in 2006, Dan has made transformative contributions to structural reliability, optimization, and sustainable infrastructure management," says Shamim Pakzad, a professor of civil and environmental engineering and department chair. "His work represents the dedication to research and scholarship that our department strives to cultivate."

A fresh approach to fracking's salty byproduct

Researchers develop a groundbreaking method to clean and capitalize on hypersaline brine

Seemingly miraculous innovations have made it possible to slake the ever-growing thirsts of our industrial society.

Need more energy? Frack it from deep-bedded rocks. Fresh water? Desalinate ocean flows. Precious metals? Leach them from previously un-minable low-grade ores.

But these and other marvels leave us awash in a sea of hypersaline brine—wastewater containing levels of salt several times higher than seawater and often contaminated with pollutants.

"The disposal of brine solutions with total dissolved solids greater than 60,000 mg L−1 poses technical, environmental and economic hurdles that remain mostly unresolved," says Arup SenGupta, Professor of Civil and Environmental Engineering, Emeritus.

Fracking operations often rely on open-air evaporation pools, a practice that is inefficient, weather-dependent, and capable of concentrating contaminants that threaten groundwater and surrounding environments.

However, a new approach developed by SenGupta and visiting researcher Hao Chen '23 PhD (then a doctoral student) represents a leap forward in cleaning up and potentially unlocking valuable resources in the super-salty water. Their innovation is detailed in a study published in the October 2024 issue of *Nature Water*.

Crystallizing a solution

The team has developed a new process called evaporative ion exchange (EIX), which concentrates brine at room temperature using air humidity and ion exchange to drive the process. Unlike existing multistage thermal distillation and membrane distillation methods, EIX avoids scale buildup and consequent fouling of equipment, and operates significantly faster than natural evaporation due to high surface area of the ion exchange resin beads.

The process uses a polymeric ion exchange resin bead—a gel-like material imbued with a high concentration of charged functional groups. These groups bind ions of opposite charge, enabling the beads to absorb water quickly while rejecting salts and other compounds. According to SenGupta, this phenomenon resembles forward osmosis, although no semipermeable membrane is involved. Instead, the ion exchanger–water interface acts as a semipermeable membrane, ensuring rapid water uptake. When exposed to unsaturated air, the resin releases the absorbed water into the air through evaporation—without external heat input.

"This cycle can be repeated, allowing the resin to continuously concentrate solutions at ambient temperature," SenGupta says. "The process is rapid, and the total energy requirement is provided by the ambient air."

Testing the Waters

The researchers conducted experiments using both synthetic hypersaline brine and brine samples collected from gas well sites in the Pennsylvania and New Jersey Marcellus Shale region. The Marcellus brine contained high concentrations of barium, strontium, and calcium ions. In the experiments, EIX beads were placed in a bed, covered with brine until saturation, and drained. The beads were then exposed to blown, unheated air for evaporation. The remaining brine's volume and total dissolved solids (TDS) were measured after each cycle.

After three cycles with synthetic brine, the volume was reduced by nearly threefold, and TDS increased by the same factor. By contrast, resin beads without ion exchange functional groups achieved less than a 20 percent increase in TDS.

When applied to the Marcellus sample, the process achieved direct crystallization of salts such as barium chloride and sodium chloride after four cycles. These results were achieved without scaling or fouling of the resin, and the method showed potential for recovering lithium—a critical material for batteries and clean energy technologies—from naturally occurring hypersaline brine.

"The most remarkable finding of this study is the precipitation/crystallization of salts from the hypersaline water from a Marcellus gas well after four EIX cycles at ambient temperature," says SenGupta. "According to the literature, no other brine concentration process attains incipient crystallization at ambient temperature."

The study was funded by the U.S. Bureau of Reclamation, the Pennsylvania Infrastructure Technology Alliance, and a Lehigh faculty innovation grant.

Scaling the vision

SenGupta is optimistic about scaling the process for widespread use, citing its simplicity and efficiency. The next steps involve running a pilot system to validate process parameters and energy advantages over existing methods that require elevated temperatures.

"The EIX process does not need any specialty material to be manufactured," says SenGupta. "It does not need any heat or major energy source. It can be rapidly scaled up."

DRNADIGI/ISTOCK

Customizable ceramics for next-gen technologies and devices

Developing ceramics with tailored geometries has long been a challenge. Achieving that kind of customization would allow materials to be designed with specific shapes and structures that make them stronger, more heat-resistant, or better at conducting electricity. Such materials could then enable more efficient electronics, better sensors, or even new types of energy devices.

Materials science and engineering researchers Helen M. Chan (pictured, top right), New Jersey Zinc Professor, and Jeffrey M. Rickman, Class of '61 Professor, have received funding from the National Science Foundation to continue a project using a novel approach that could potentially revolutionize the fabrication of ceramics.

"The systems we're studying give us the potential for predetermining the microstructure," says Chan, "almost like templating."

The goal is to produce a functional material with a tailored geometry—or microstructure—that will allow for a range of applications.

To that end, the team has exploited a method called solid-state synthesis, which involves a chemical reaction between two distinct phases, leading to the formation of a new, third phase (called a product phase) that has a specific, controlled geometry. In this case, the desired product phase is an entropy-stabilized ceramic that is thermodynamically stable at high temperatures. This approach is not about creating just any new material but, rather, crafting it with precision, enabling new functionalities that were previously out of reach.

The team made an unexpected discovery about this third phase early on.

"That third phase was a single crystal, and it's difficult to get single-crystal growth you can template," Chan says. "The combination of the single-crystal interface with those other two phases could, in fact, contribute to the functional properties of the system."

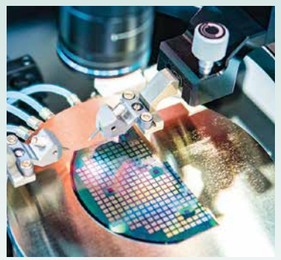
The ability to produce single-crystal phases with specific microstructures could lead to advances in electronics, energy conversion, and more. For example, the resulting materials could be used in thermoelectric devices that generate electricity from waste heat. Beyond these applications, the research, which combines experimental work with advanced modeling, also aims to answer fundamental questions about the processes involved in solid-state synthesis.

"We want to better understand the physics behind the reaction, and the modeling aspect will allow us to model the formation of this new useful phase," says Rickman. "How do the atoms come together? How does the material deform during a reaction? How does this long-range transport of the atoms at the interface occur? It's an interesting project in that we're both producing new and useful products, but we're also contributing to the fundamental science driving these reactions."

"WE'RE CONTRIBUTING TO THE FUNDAMENTAL SCIENCE DRIVING THESE REACTIONS."

—Jeffrey M. Rickman

AI-DRIVEN QUALITY CONTROL IN SEMICONDUCTOR MANUFACTURING



TOP: SHOTBYVASGAR; BOTTOM: GRISPB/ADOBE STOCK

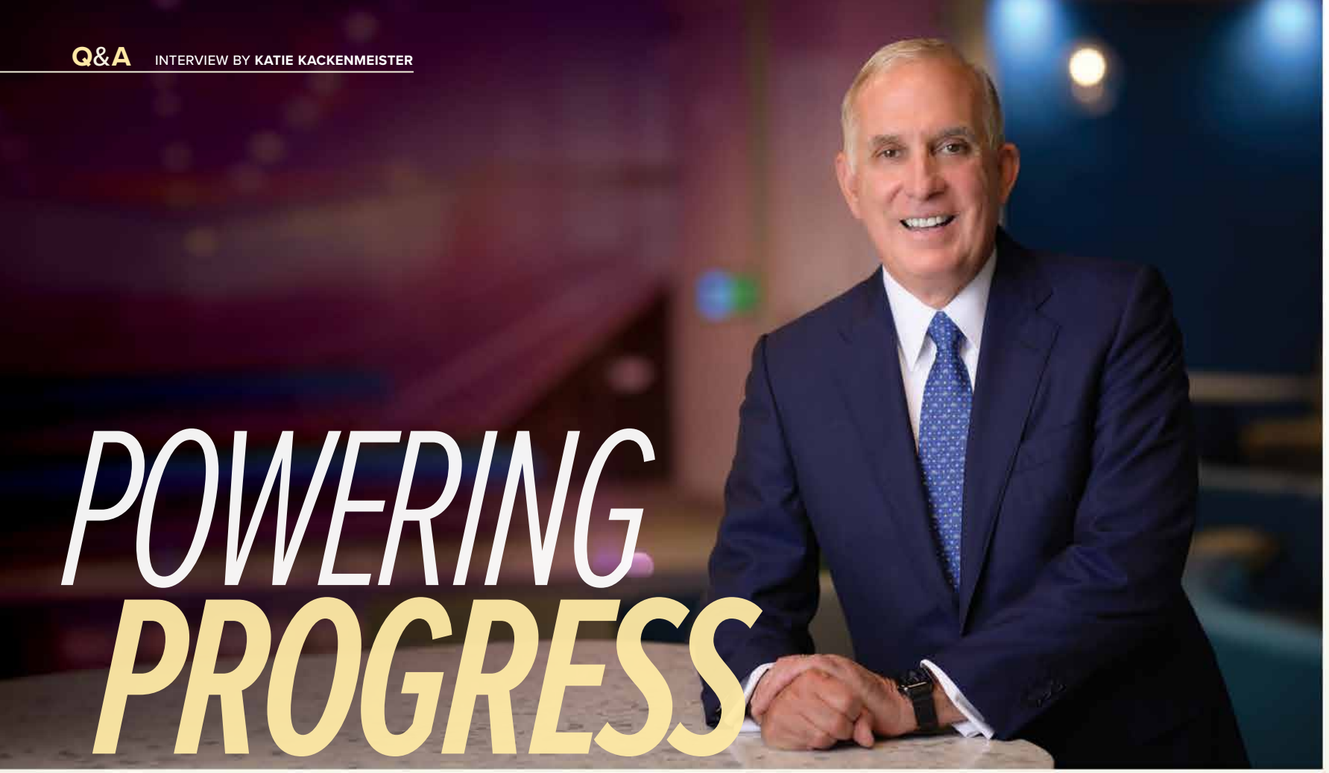
Semiconductor chips—tiny, intricate discs used in electrical and photonic devices—are built through a highly complex, multilayered production process that Zheng Yao, principal research scientist in Lehigh's Energy Research Center, says is among the most sophisticated in manufacturing. Quality control during this process is essential.

Yao has partnered with Broadcom, which manufactures the chips in a Lehigh Valley facility, on a research project aimed at improving quality-control practices on the production line. Currently, engineers manually inspect data and microscopic images of semiconductors, a process that Yao calls "time-consuming and also very subjective."

If two or more quality-control engineers have different thoughts on one product, time can be lost resolving the issue, he explains. With tens of thousands of chips produced every day, this method can significantly delay operations.

Yao's team is introducing machine learning to transform this process. Their project, funded in part by the Pennsylvania Infrastructure Technology Alliance, uses artificial intelligence to analyze data, classify images, and assess product quality without interrupting production. Early results have been promising, and Broadcom has expressed interest in scaling the tools.

Collaborating on this project are two assistant professors in the Department of Computer Science and Engineering. Yu Yang specializes in mobile sensing, spatio-temporal machine learning, and reinforcement learning, bridging human and cyber technologies. Lifang He focuses on machine learning, data mining, and biomedical informatics. Graduate students also play a pivotal role in the effort. "We are helping the students to develop a way of thinking and exploring independently in the future," says Yao.



POWERING PROGRESS

Lew Hay ’77 on advancing clean energy, building resilient infrastructure, and giving back to Lehigh

For Lew Hay, a Lehigh engineering education was more than a launching pad—it was a proving ground. Drawn to electrical engineering for its rigor, he found that the problem-solving mindset he developed at Lehigh would serve him well throughout his career in corporate leadership. After early roles in consulting and finance, Hay rose to lead Florida-based NextEra Energy (formerly FPL Group), which became the leading producer of renewable energy as well as the largest electric company in North America by market capitalization. He retired as president, CEO, and chairman of the board in 2013. Now, through a transformational gift, he and his wife, Sherry, are investing in the future of engineering education at Lehigh. Their endowment will support the dean of the Rossin College—formally naming the Lewis Hay III ’77 ’08P ’11P and Sherry A. Hay ’78 ’08P ’11P Deanship—to help the college attract visionary leaders, drive groundbreaking research, and expand opportunities for students, including the burgeoning First-Year Rossin Experience (FYRE). “I like to invest in people, and it takes great professors and great leaders to really differentiate a program,” says Hay, who currently serves on corporate boards and advises organizations focused on sustainability and innovation, sharing his engineering-informed perspective on solving critical challenges in the energy sector and beyond.

Q: What do you see as key to accelerating the growth of renewable energy in the U.S.?

A: For the longest time, renewables were expensive—more expensive than coal or gas or nuclear. That’s not the case anymore. Solar and wind are, on a per megawatt hour basis of electricity generated, the cheapest forms of energy we have. But they are intermittent, so for them to become a bigger share of the U.S. energy mix, we need more energy storage, meaning battery storage. The technology has come a long way, but it’s still costly, so it’s being deployed selectively. It’s no different than with automobiles. As the price of batteries comes down, you’re going to have more storage in the electric utility industry and you’re going to have more electric cars.

Another big hurdle is getting what we call interconnection agreements with local utilities to connect wind farms and solar plants into the grid. There’s a massive backlog for companies to get these approved, so we need to streamline and speed up that process. One of the contributing factors is that we don’t have enough transmission capacity in the United States. Most solar farms are located in somewhat remote areas. You need to be able to get the electricity to the “load centers” where people use the energy. We as a nation have to build more transmission to accommodate that. There are numerous challenges in building transmission: It’s not cheap to build and siting it isn’t easy, especially when you start crossing state lines.

Q: Are there other emerging sources of renewable energy that hold promise?

A: One that gets a lot of hype right now is nuclear power, in the form of small modular reactors. These would be much smaller than reactors built in the past, which are now prohibitively expensive. They’d be manufactured on an assembly line and then shipped to a location, theoretically making it much cheaper. I’m a big fan of nuclear power. It’s very clean and safe. But I’m skeptical about the economics. It’s very hard to get a real-world estimate of what small modular reactors will cost. So I think solar and wind are going to be the renewables of choice for at least the next 10 to 15 years.

Q: What does “resilient infrastructure” mean in an energy context?

A: Resiliency of the electricity supply is the provision of reliable electricity regardless of external factors. In Florida, we think of hurricanes, of course, but it’s much more than that. We have birds and squirrels and all sorts of creatures that create problems. Electromagnetic radiation from solar flares can do a number on electronic equipment. And then there’s cybersecurity. The electrical grid and all our systems are constantly being attacked.

We always viewed it as our job to keep the lights on, and it’s become increasingly important. The typical home has dozens of electrical devices that connect to the internet, and power is central to everybody’s lives. When I was a kid, we lost power fairly frequently in Western Pennsylvania, but you’d light a few candles and wait it out. People can’t do that today. And in Florida, if you lose power in the summer, it becomes a threat to people’s health. So we focused a lot on resiliency.

In 2003 and 2004, we had seven hurricanes hit our service territory. With every one, we had millions of customers without service and had to bring in 15,000 to 20,000 linemen from all over to help put our grids back together. Every single person in our company was working on it. At first, we got the power back quickly. People called all the lineman heroes. By the last hurricane, people were pretty upset after multiple experiences of going for days without power. It wasn’t good for our customers or our business. So we embarked on a program, called Storm Secure, to improve resiliency. Even though our network had already been built to higher standards, it wasn’t sufficiently durable to hold up to massive hurricanes that would hover for days. With Hurricane Wilma, at one point we had 4.5 million customers out of power and it took several weeks to get everybody back on. At that scale, people have a hard time just living their normal lives. They can’t drive their cars. They worry about safe food and water.

First, we hardened major thoroughfares up and down the state—main roads with four or five grocery stores, multiple gas stations, convenience stores, and so on. We looked at those areas first so people could access the basic necessities. We also prioritized hospitals and police and fire stations, and then slowly started building out from there. Our ultimate goal was getting our entire transmission network—what moves the power from a power plant—closer to load centers, or the major cities. It’s taken close to 20 years to harden the entire grid and make it more intelligent. In many cases, even when you have a fault, the grid can automatically flip switches to work its way around that fault and keep as many people with power as possible.

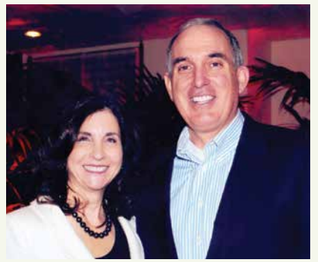
Q: What impact has artificial intelligence had on the power industry?

A: There’s a lot of talk recently about AI. But in the energy industry, we’ve been working with machine learning and other forms of artificial intelligence for close to 10 years—the applications just continue to expand. A simple example involves the inspections we do on our lines periodically looking for components on the verge of failure. Historically, we would have people with binoculars in helicopters and trucks patrolling transmission lines. It was a very time-consuming process and not all that effective in finding subtle issues. Now, drones equipped with cameras connect to computers that use image recognition to identify even the smallest of issues that could cause a line to fail. They take thousands of images, and AI can sort through them incredibly fast while identifying problems that humans would most likely miss.

We’re also hearing a lot about increased energy demand as a result of the growing adoption of AI. Go to any energy conference and it’s all they’re talking about. There are all sorts of estimates out there. What compounds the challenge is that tech companies want clean energy for their data centers. Overall, it’s going to create a big demand for renewables, but I don’t see that they will be able to satisfy the demand. I think some coal plants that have been scheduled to be shut down are going to keep running. More gas plants and more transmission will need to be built. Then again, AI models may also become more energy efficient, as is apparently the case with the Chinese startup DeepSeek that has been in the news. We’re definitely going to see growth in demands for electricity, but it might not be as big as some people are forecasting.

Q: What drew you to electrical engineering and how did your Lehigh education serve you in your career?

A: When I had to decide on a discipline, upperclassmen told me that electrical engineering was the hardest major. They said: “If you can do electrical engineering, you can do anything.” So I selected it because of the challenge it posed. Being an electrical engineer gave me credibility with the engineers and technical staff when I became CEO of FPL Group. My background in engineering provided a framework and systematic approach for analyzing and solving problems in business, which I relied on throughout my career. At Lehigh, I learned to be disciplined and use my time efficiently. That honed some muscles that I used for the rest of my career.



COURTESY OF LEWIS HAY III/FPL SOLAR/NEXTERA ENERGY

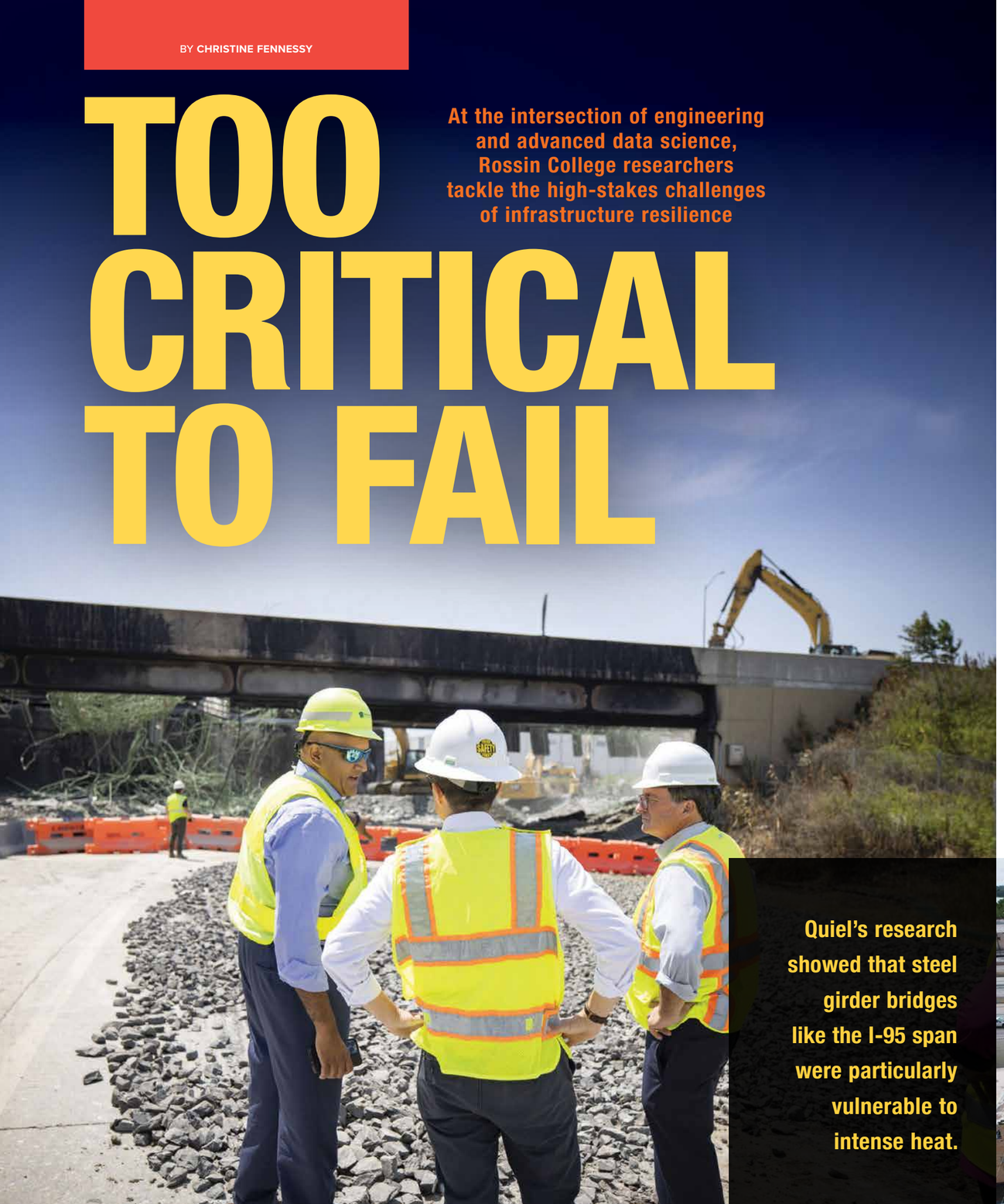
COURTESY OF ARTERA

According to Hay, supporting the university while associating their name with Lehigh Engineering struck the Hay family as a special opportunity.

BY **CHRISTINE FENNESSY**

TOO CRITICAL TO FAIL

At the intersection of engineering and advanced data science, Rossin College researchers tackle the high-stakes challenges of infrastructure resilience



COURTESY OF COMMONWEALTH MEDIA SERVICES

Quiel's research showed that steel girder bridges like the I-95 span were particularly vulnerable to intense heat.

IT'S NO SECRET THAT OUR INFRASTRUCTURE takes a beating. You see it in the fresh crop of potholes you encounter on the roads each spring and the news reports that flash the devastating toll of storms and wildfires across your screens. Communities are facing increasing challenges from climate change, population growth, and evolving technological threats, while the costs of maintaining and replacing infrastructure continue to rise. In response, ensuring that essential systems can withstand and recover from disruptions is a top priority.

Data science is at the heart of efforts to make infrastructure more resilient. Advanced analytics, machine learning, and predictive modeling allow researchers to assess risks, optimize resource management, and develop smarter strategies for disaster preparedness and recovery. From predicting when bridges will need repairs to strengthening the reliability of the power grid, data-driven insights are transforming how we build and protect infrastructure.

Lehigh has leveraged its strength as a data science powerhouse in the creation of two University Research Centers dedicated to fortifying infrastructure and communities: the Center for Catastrophe Modeling and Resilience and the new Center for Advancing Community Electrification Solutions (see page 15). Additionally, the Department of Energy funded Lehigh's Climate Resilience Center, which analyzes extreme water events like droughts and floods in the Lehigh Valley to assess the impact of climate action plans and better understand how different population groups respond to these events.

Beyond these centers, Rossin College faculty are using novel data science tools to measure and mitigate potential flood risk caused by climate change and to conduct innovative research that will protect our ports and bridges. The effectiveness of such efforts is a direct result of the university's commitment to taking an interdisciplinary approach to study and advance infrastructure resilience, says Brian Davison, a professor of computer science and engineering and department chair.

"That's what sets us apart as an institution," says Davison. "We combine expertise across disciplines to create solutions that not only address today's most pressing issues, but anticipate those we'll face in the future. Whether we're using predictive modeling to prepare for natural disasters or developing sustainable energy solutions for communities, our commitment to collaboration and cutting-edge research demonstrates how we use data science as a powerful tool for real-world impact."

Advancing fire-resistant design

In June 2023, a tanker truck crashed and ignited beneath a bridge on Interstate 95 in Philadelphia, causing the northbound lanes to collapse and severely damaging the southbound lanes. Following the incident, the Pennsylvania Department of Transportation (PennDOT) commissioned engineers at Lehigh to conduct a forensic analysis in which the team modeled the fire by simulating the heat output and spread, assessed how that heat affected the bridge's components, and evaluated the resulting structural responses.

"Our predictive model performed well," says Spencer Quiel, an associate professor of civil and environmental engineering, who contributed to the report. "It took about 12 minutes for the first collapse of the northbound span, and the southbound span was sagging significantly when the fire ended about an hour later. Our model closely matched each of the observed milestones during and after the fire."

Quiel and his team also found that steel girder bridges like the I-95 span were particularly vulnerable when subjected to intense heat; they recommended that heat-resistant coatings could be used to enhance resilience. (Girders are horizontal structural supports critical for strength and stability.)

"We've got three specimens of girders that we've fabricated in ATLSS [Lehigh's Advanced Technology for Large Structural Systems Engineering Research Center], and we're going to test them with different protective materials that PennDOT is interested in exploring," says Quiel.

As a structural engineer who specializes in fire as a hazard, Quiel has been part of a larger effort to add fire as a load to the ASCE 7 standard, which includes minimum design loads and associated criteria for buildings and other structures.

"We want structural engineers to think about fire not simply as something to add protection against," he says, "but to consider in terms of, what do you expect to happen, and how do those materials and structures respond? What damage are you left with? Has the thing fallen down? Is it reusable? That's a huge variation in performance. PennDOT, for example, is interested in engineering to higher levels of performance so that a structure can potentially be reused."

It's an approach that can be applied to structures of all types, and it's especially relevant at a time when wildfires now burn more frequently, for longer, and at hotter

Federal and state officials survey the fire-damaged Philadelphia bridge in June 2023; permanent repairs (inset) were completed less than a year later.

> "Our commitment to collaboration and cutting-edge research demonstrates how we use data science as a powerful tool for real-world impact." —Brian Davison

temperatures. Buildings and bridges can become more fire resistant if they are made of, or protected with, noncombustible cementitious or stonelike material. Quiel's research combines physical testing with numerical modeling to determine this response.

For the girder project, the team will first conduct small tests to gather input properties to feed the models. Then they will move on to bigger tests to model different spans—the horizontal section between supports—along with different girder styles and fire durations to gain a more complete understanding of the fire load. The results of these tests validate the models at the element level, and the models can then be used to generate new understanding at the system level. Quiel has done similar work to determine the fire protection rating of floor systems in buildings through a fellowship grant from the American Institute of Steel Construction.

Predicting the impact of cascading hazards

Cláudia Reis, an assistant professor of civil and environmental engineering, has a fascination with maritime ports. In countless ways, these industrial harbors enable life as we know it. According to a report by the United Nations Conference on Trade and Development, more than 80 percent of the volume in international trade is transported by sea.

However, design considerations "are often overlooked or disregarded," says Reis, who works within Lehigh's Institute for Cyber Physical Infrastructure and Energy (I-CPIE). "The design of busy ports, which are critical societal infrastructure in regular conditions or even lifeline infrastructure in the case of extreme events, needs to follow operational criteria to prevent disruptions. This requires acknowledging ports' location in hazard-prone regions and vulnerability to the effects of climate change, such as rising sea levels, which intensify the frequency and severity of natural disasters."

Work in Reis' lab focuses on characterizing the structural behavior of coastal and offshore infrastructure in response to natural hazards with hydraulic components. Specifically, the group explores how water, soil, and structures interact across what she calls the three M's—multiscales, multiphysics, and multihazards. For example, how an earthquake followed by a tsunami or the wind and the waves of a hurricane will affect infrastructure elements as a synergistic system.

Port Fourchon in Louisiana (above) took a direct hit from the damaging winds and storm surge of Hurricane Ida (top) in 2021.

"Instead of considering individual loads from a single hazard, you have cumulative, cascading effects that further weaken the structure," she says. "And besides the interaction between the natural and the built environment, the interactions among the components of the infrastructure are also considered. So now you're concerned about not only the deck of the bridge or the wharf, for instance, but the foundation as well."

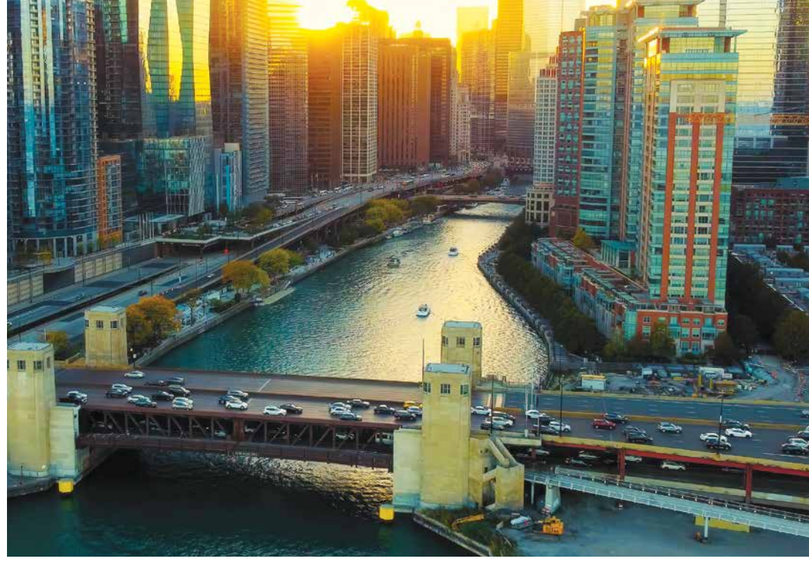
Based on what we know from previous events, Reis continues, "the effects of an earthquake followed by series of tsunami waves induce a combination of soil liquefaction and scouring of the foundations that amplifies the progressive loss of structural resistance. Understanding these interactions will better inform the design and resilience of these critical pieces of infrastructure."

To that end, Reis uses numerical modeling to solve complex fluid dynamics problems (such as those caused by hurricane and tsunami waves) and simulations to model fluid-structure interactions. The group also develops numerical schemes, physical models tested under controlled laboratory conditions and, lately, cyber-physical approaches to address the "three M's" problems characteristic of coastal and offshore engineering.

"Our goal is to keep our close engagement with industry partners to provide recommendations for their real-world problems," she says. For instance, the group is investigating the reinforcement of decks to withstand hydrodynamic loads on the vertical and horizontal components of ports and bridges. Another concern from stakeholders relates to countermeasures to reduce the effects of scour around the piles. "We'll do complementary physical-numerical simulations, and in the end, we'll have recommendations."

Such recommendations are now going into updated design codes that can be applied to new structures and used in the rebuilding or rehabilitation of existing infrastructure. The ultimate goal, she says, is to improve the resiliency of coastal communities and prepare them for scenarios that apply today, as well in 50 or even 100 years from now.

Reis uses computer models to study hurricane-driven waves and wind and how they interact with infrastructure.



LEFT: COURTESY U.S. SEN. BILL CASSIDY; CENTER: COURTESY OF NOAA

RIGHT: IRYNA OLKHOVA/ISTOCK

Turning smartphone data into bridge health insights

Budget is often the limiting factor when it comes to the maintenance of our nation's transportation system.

"Infrastructure in the United States is aging," says Shamim Pakzad, a professor of civil and environmental engineering and department chair. "In particular, our bridges are aging, and they represent some of our most expensive and critical assets. It's a problem that will take trillions of dollars to address."

Pakzad, who is an expert in structural health monitoring, has devoted his research to developing the methods, mechanisms, and algorithms that provide essential information about the condition of infrastructure systems, specifically bridges. His work is shedding light on whether these critical structures need repair or maintenance immediately—or in 2, 5, or 20 years.

He and his team have developed an app that employs the accelerometers in smartphones to collect vibration data (while traveling over a bridge), and they use it to determine structural integrity. When the app senses it's going over a bridge (through geo-fencing), the accelerometer takes vibration measures from the vehicle's contact with the surface and sends the data to a cloud location for further processing. The vibrations present as frequencies—or pitches—that indicate stiffness. As a structure degrades, its stiffness decreases.

"When pitch changes, it indicates a softening," he says. "We've shown that we can translate acceleration data, which is the response of the structure, into stiffness measures."

Having shown that his algorithms work to convert accelerometer data into usable information about bridge degradation, he is taking his research to the next level through transfer learning. In transfer learning, a model trained for one task can be applied as a starting point of sorts to another model involved in a similar task. It streamlines the training for the second model because it is incorporating characteristics from the former.

Their goal now is to measure strain this way.

> "Studies to determine a structure's condition come with a high price tag. We want to give decision-makers that information essentially for free."
>
> —Shamim Pakzad

"Strain can be translated to stress, and stress is basically a measure of how much force you have at each point in your structure," he says. "To estimate the degradation due to repeated use, what we really want to know is the level and frequency of stress at each point in the structure, but we can't measure that directly. We aim, however, to measure it indirectly through accelerations."

All bridges can endure a certain amount of strain, or stress. Every time a vehicle passes over the span, it exerts a certain level of load that produces some degree of stress. Over time, millions of these cycles can cause fatigue cracks. The goal is to understand how many cycles of higher stress a bridge component can safely endure, and then figure out how much of that capacity is left, for any given bridge.

"You measure how many cycles of fatigue load a structural component is experiencing in a defined period of time," Pakzad says. Then, knowing the bridge's age, he explains, researchers can determine how many cycles it has experienced in the past and figure out how many years are left before it is likely to break.

Measuring strain/stress, however, is difficult and expensive. But Pakzad and his team have developed a new model using AI that measures acceleration data and converts it into strain data that could then be used for fatigue analysis.

"We have extensively tested our model on single bridges, but you don't want to have to do that level of testing and training of the models for every bridge. The goal is to be able to use the model for a bridge with similar characteristics. You will just make the necessary adjustments to the model, run it through crowd-sensed data, and that will give you information you need about how to manage the maintenance and repairs of this structure."

Decision-makers typically follow two philosophies regarding infrastructure repairs: schedule-based maintenance and condition-based maintenance.

Rahnemoonfar uses AI to optimize predictions of polar ice dynamics to improve the accuracy of climate models.

Greenland's ice sheet shrinks as icebergs break off from glaciers and surface melt forms rivers (inset) that accelerate ice loss.

In the future, he envisions an online platform hosting a range of bridge models, which would empower decision-makers to use their local data to inform their actions.

"It could become an important tool for asset allocation because while the major repairs of bridges are expensive, just doing the studies to determine a structure's condition currently comes with a high price tag," says Pakzad. "We want to give them that information essentially for free."

Smarter models for a changing coastline

According to the Inter-governmental Panel on Climate Change, the oceans could rise anywhere from eight inches to more than four feet by the year 2100. Such a range reflects the uncertainty inherent in making such a prediction; it's unclear how successfully the world's economies will reduce their carbon emissions, and it's still largely a mystery as to how polar ice will respond to a changing climate.

"There is so much uncertainty in the climate model that projects sea level rise, and one reason for this is because we don't understand what's happening beneath the ice," says Maryam Rahnemoonfar, an associate professor with dual appointments in civil and environmental engineering and computer science and engineering. "If we can more precisely calculate the ice thickness and the snow accumulation over years and study the spatial-temporal changes that happen over the years, we can better calibrate these models for more precise projections."

Measuring sea and land ice is a complex task. Polar regions are difficult to access regularly, and ice is extremely dynamic in how it moves and melts. And though bedrock can influence the behavior of ice sheets, it's often so far below the ice surface that it's challenging to study. In addition to ground-based measurements, satellite remote sensing and airborne surveys using lidar and radar sounding can give researchers insight into how ice changes in terms of extent, thickness, and movement. Refining these methods to provide more accurate projections is essential in helping coastal communities prepare for the potential increase in flood risk.

With 40 percent of the world's population living within 100 kilometers (or about 62 miles) of a coastline, the economic consequences of rising sea levels will be huge. Better models will enable communities and governments to mitigate those impacts.

To that end, Rahnemoonfar is leading several projects to improve the accuracy of current climate models. She and her team have developed a machine learning model that incorporates the physical laws governing polar ice behavior to better calibrate simulations and predictions related to sea ice dynamics.

"Previous models focused on either the velocity or the concentration of the ice, but we developed a model that can actually predict those simultaneously," she says. "This project develops a novel neural network architecture to predict daily sea ice concentration and drift, allowing information sharing between the tasks to improve prediction performance."

In a second project, they developed an experimental machine learning model called a multibranch, spatiotemporal graph neural network that could work in tandem with information generated by the radar sensors used on land ice. The model can more efficiently process the huge amount of data collected by the radar, plus, it can use the radar data generated from the top layers of ice, which is less noisy and more accurate than results from deeper layers, and use that to predict the thickness of deeper layers.

A third project develops a graph neural network emulator for the ice sheet and sea level system model. "The existing numerical and physical models are super expensive and highly computational," she says. "We've been able to show that our model uses fewer resources to work faster and with the same accuracy."

Reducing uncertainty in sea level rise projections, she says, will enable communities to adapt to future realities.

"Better models will help people better prepare."

MAIN: NASA/JPL-CALTECH; INSET: MARIA-JOSÉ VIÑAS/NASA EARTH SCIENCE NEWS TEAM

LEHIGH LAUNCHES NEW UNIVERSITY RESEARCH CENTERS

TWO NEWLY ESTABLISHED UNIVERSITY RESEARCH CENTERS will address critical societal needs, joining the Center for Catastrophe Modeling and Resilience, Lehigh's first URC, which was launched last year to enhance the accuracy of disaster predictions and assessments using cutting-edge technologies and analytics.

The Center for Advancing Community Electrification Solutions (ACES) will focus on electrification across three common energy-intensive sectors—transportation, water, and buildings—as well as adaptations to the supporting local power grid. Shalinee Kishore, Iacocca Chair Professor of Electrical and Computer Engineering, and Arindam Banerjee, Paul B. Reinhold Professor of Mechanical Engineering and Mechanics and department chair, will lead the center as it seeks to transform how communities use electricity by creating efficient, reliable, and self-sustaining energy systems.

CENTER FOR ADVANCING COMMUNITY ELECTRIFICATION SOLUTIONS (ACES)

ACES' work will focus on the development of "electricity-sheds" within a community to optimize power use, storage, and delivery. An electricity-shed (conceptually similar to a watershed) is a region, community, or industrial area that requires supporting power grids to provide locally generated electricity to meet electrification needs for buildings, transportation, and water systems. Electricity-sheds must be efficient, secure, and flexible while working within an integrated electricity system.

"ACES aims to deliver energy independence and efficiency to a range of communities through electrification, which is a growing force in our economy," Kishore says. "It is predicted that electricity needs will grow significantly in the next several decades as we switch to power many of our energy-intensive processes through electricity and with increased demand from energy-intensive computing in data centers."

Kishore noted that work originating from ACES may be applied to understanding communities that are seeing the increased use of electric vehicles, growing dependence on electric pumps to run water distribution systems, and higher electricity demands due to the power requirements of smart manufacturing facilities and AI data centers.

ACES will combine technology solutions with community needs, helping to reduce energy costs and promote energy security and independence. Faculty affiliated with the center will conduct interdisciplinary research in engineering, economics, social science, policy, and data science to assess how to optimize functions and community impact of electricity-sheds. With strong partnerships and workforce development initiatives, ACES will lead the way in making electrification scalable and accessible.

The Center for Community-Driven Assistive Technologies (CDAT) aims to transform the lives of people with physical, cognitive, behavioral/emotional, sensory, and developmental disabilities through interdisciplinary research and cutting-edge assistive technologies. The center will focus on life transitions, mobility enhancement, everyday activities, and access to living, working, and learning spaces.

The interdisciplinary research conducted at CDAT will develop new and innovative approaches to empowering people with disabilities and expand opportunities in education, employment, and health. Researchers will take a unique holistic approach that begins by engaging those community members who are most affected—and emphasizes collaboration with service providers to guide translational innovation—to develop impactful solutions tailored to real-world needs. While partnering with an array of stakeholders, the center aspires to be a national leader in advancing independence, accessibility, and quality of life for people with disabilities.

CENTER FOR COMMUNITY-DRIVEN ASSISTIVE TECHNOLOGIES (CDAT)

CDAT has been developed through collaboration among faculty from the Rossin College, the College of Health, and the College of Education. The center will be led by Vinod Namboodiri, Forlenza Chair of Health Innovation and Technology and a professor of computer science and engineering, and George DuPaul, a professor of school psychology. Faculty and students from across the university will have opportunities to engage in the important work of the center.

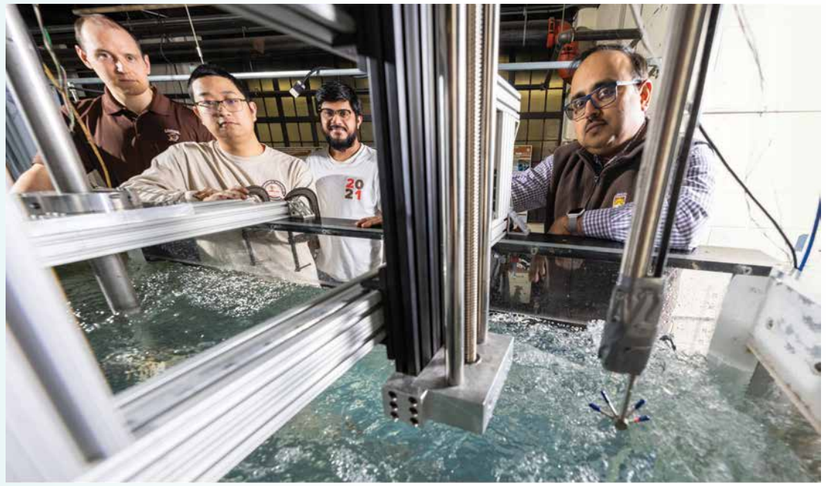
"Advancements in medical care have resulted in people living longer lives, which means more people are reaching ages where disability becomes more prevalent," Namboodiri says. "Assistive technologies are crucial because they can help bridge the gap for individuals with disabilities or impairments, allowing them to live a more independent or interdependent life that is fulfilling. These technologies make tasks that might otherwise be difficult or impossible, more manageable." *—Kristen DiPrinzio*

MARCUS SMITH '25

The next wave

A major grant to the Atlantic Marine Energy Center powers new research, infrastructure upgrades, and expanded education initiatives

The ocean holds vast, untapped potential: Engineers see it as a resource to store carbon and help mitigate climate change, an avenue to address food and fresh water insecurity, and a source of sustainable materials and life-saving medicines.



Banerjee (right) leads the Tidal Turbulence Test Facility, which will play a key role in the university's expanded marine energy research.

At Lehigh, researchers are immersed in efforts to harness its waves, tides, and currents to drive innovation in renewable energy.

Nearly four years ago, the Atlantic Marine Energy Center (AMEC), a partnership among the University of New Hampshire (UNH), Stony Brook University, the Coastal Studies Institute, and Lehigh, began its mission to turn the vast energy of the ocean into a sustainable power source. Now, with a $12 million grant from the Department of Energy, AMEC is poised to deepen its impact—launching innovative research projects, improving infrastructure, and equipping a new generation of engineers to address the world's energy challenges.

In total, DOE's Water Power Technologies Office invested more than $41 million in this latest round of funding through the Bipartisan Infrastructure Law to support four university-led National Marine Energy Centers located across the country. The centers will use the funds to support research, infrastructure improvements, strategy, administration, outreach, and communications for their projects.

The grant follows the $9.7 million that DOE awarded the four AMEC universities in 2021, which served to establish the center.

"This is a five-year award that will allow us to expand the scope and reach of AMEC," says its co-director, Arindam Banerjee, who is Lehigh's Paul B. Reinhold Professor of Mechanical Engineering and Mechanics and department chair. "And we'll be doing that by, among other efforts, developing a series of weeklong summer courses, launching new research projects, and improving our test facilities."

The new courses are currently being developed by the AMEC leadership team across the four institutions. They will kick off this summer with an Introduction to Marine Energy short course held at UNH. In total, up to five new classes will be offered, covering topics including instrumentation for marine energy, marine resource characterization, coastal microgrids, and flexible structures for marine energy. Some will be open to all; others will target students and professionals currently researching and/or working in the field.

"We'll have two tiers of courses," says Banerjee. "The first will be like a boot camp, where students will be exposed to the fundamentals of marine energy systems. It might attract, for example, a senior from any engineering major who is curious about marine energy but doesn't want to commit to a traditional course. They'll get a good introduction to the fundamentals and the experts, and hopefully it will help guide their decision about graduate school. The second tier of classes will be highly specialized, graduate-level courses that give students and professionals an immersive experience in a single topic within marine energy."

A second key part of this newest grant will see Lehigh take the lead on two research projects—one focused on the structural performance of tidal turbine blades under turbulent loading, and the other on real-time stable marine energy microgrid power management for coastal communities.

"Our original AMEC team here at Lehigh consists of seven faculty members, and we've now added three more, all of whom are involved in these projects," says Banerjee, who will be running the first project out of his own lab, Lehigh's Tidal Turbulence Test Facility.

That project will involve small-scale testing of turbine blades in Banerjee's lab followed by large-scale numerical simulations at Lehigh's High-Performance Computing Center conducted by Parisa Khodabakshi, an assistant professor of mechanical engineering and mechanics and one of the new faculty members of AMEC. Large-scale experiments will be performed at Lehigh's Advanced Technology for Large Structural Systems (ATLSS) Engineering Research Center by Richard Sause, the Joseph T. Stuart Professor of Structural Engineering.

"Typically, experiments or simulations are done at one scale," says Banerjee. "This is a unique study in that we're doing experiments across scales and using simulations to serve as a bridge between them."

The second project will attempt to integrate marine renewable energy resources, in this case, wave energy converters, into coastal microgrids. It's a multidisciplinary effort that includes Farrah Moazeni, an assistant professor of civil and environmental engineering; Javad Khazaei, an assistant professor of electrical and computer engineering (both of whom are among the latest to join AMEC); and Banerjee.

"Our aim is to design a real-time, closed-loop control system for marine energy microgrids that not only optimally allocates energy resources, but also guarantees stability in the face of fluctuations and uncertainties from loads, weather, and renewable resources," says Moazeni, who will lead the project as well as teach one of the advanced short courses. "Coastal and island communities often lack access to reliable and stable energy sources. With this grant, I hope we can take a meaningful step toward providing stable energy resources capable of withstanding the challenges posed by climate change to these communities."

Additionally, Lehigh will contribute data and the expertise of Muhannad Suleiman and Paolo Bocchini—both professors in the Department of Civil and Environmental Engineering and members of AMEC—to several other projects led by other institutions within the center.

The grant also supports more infrastructure improvements that will facilitate both these and future projects. For example, Khazaei, who is the director of the Integrated, Resilient, and Intelligent Energy Systems (INTEGRITY) Laboratory—will lead the development of a multi-port converter for marine renewable energy integration to coastal community microgrids.

"There is significant potential for energy extraction from the ocean, which is an area that remains largely underexplored," says Khazaei. "This latest AMEC award offers Lehigh the opportunity to delve into new research areas and foster multidisciplinary collaborations that were previously out of reach."

As part of the award, the Lehigh team will also conduct community outreach to showcase the work of the center, contribute to ongoing strategy and implementation plans for AMEC—and for all the nation's marine energy centers—and participate in performance reviews.

"The first AMEC award got Lehigh established as a center, and with this latest funding, we're starting the real work of making marine energy part of the solution to decarbonization and to meeting our nation's energy needs," says Banerjee. "I'd love to time travel to July 2029 when the period for this grant is up to see all that we've accomplished. It's a very exciting time to be in this field and to lead a group of faculty members who are all committed to sustainability and making the planet a better place to live in for our future generations." —*Christine Fennessy*

"I HOPE WE CAN TAKE A MEANINGFUL STEP TOWARD PROVIDING STABLE ENERGY RESOURCES FOR COMMUNITIES FACING CLIMATE CHALLENGES." —Farrah Moazeni

RYAN HULVAT/MERIS

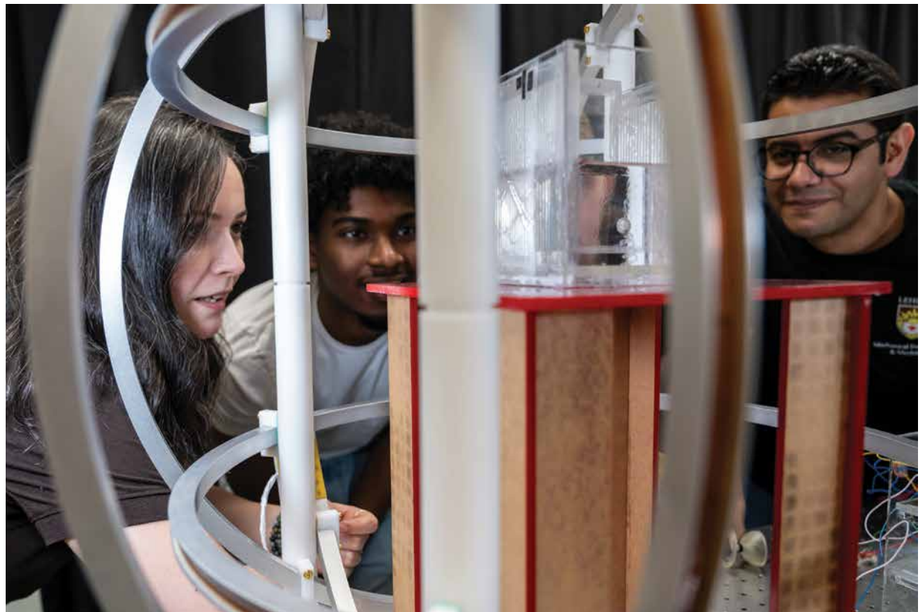
JEREMY BISHOP/ADOBE STOCK

BY CHRISTINE FENNESSY

DRIVEN BY A PASSION FOR DISCOVERY, these Lehigh Engineering faculty members are pushing the frontiers of gene editing, robotics, AI-driven design, and medical diagnostics. Their work has earned national recognition through two prestigious honors: the National Science Foundation's Faculty Early Career Development (NSF CAREER) award, which recognizes junior faculty who excel as teacher-scholars, and the Presidential Early Career Award for Scientists and Engineers (PECASE), the highest U.S. government honor for early-career researchers in science and engineering. These accolades affirm not only their individual achievements but also the strength of Lehigh's research ecosystem—one that nurtures big ideas and empowers faculty to make a lasting impact.

UNLIMITED POTENTIAL

National early-career honors highlight the impact and ambition of Lehigh Engineering faculty

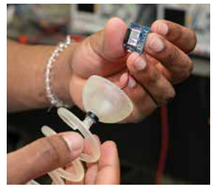


Demir (left) and team with a three-axis Helmholtz coil system, which generates rotating magnetic fields for wireless actuation of microswimmers.

PHOTOS BY CHRISTA NEU

EBRU DEMIR:
Teaming up tiny robot swimmers

Smart artificial microswimmers—small robots that resemble microorganisms like bacteria or human sperm—could potentially be used for targeted drug delivery, minimally invasive surgery, and even in fertility treatments.



These types of complicated tasks won't be accomplished by a single microswimmer. Multiple swimmers will be necessary; however, it's unclear how such groups will move within the chemically and mechanically complex environment of the body's fluids.

"We know that whenever a swimmer has a neighbor, it swims differently," says Ebru Demir, an assistant professor of mechanical engineering and mechanics. "Birds fly in a V formation because it's more efficient and it saves them energy. But for a group of microswimmers, we don't know what the best formation looks like."

Demir recently received an NSF CAREER award for her research combining artificial microswimmers with machine learning to build Smart Artificial Microswimmers (SAMs). By embedding AI into centimeter-scale robotic swimmers and comparing their behavior with predictions from simulations, her project aims to uncover the underlying physics that govern their movement in complex fluid environments.

To study how the swimmers move in both Newtonian and non-Newtonian fluids, Demir will insert microcontrollers that run reinforcement learning algorithms into 3-D printed autonomous robots that are 10-20 centimeters, or about 4-8 inches, in size. Fluids in the human body, such as blood, have non-Newtonian properties, meaning their viscosity, or resistance to flow, changes depending on the stress applied by the swimming body. She will make and use fluids with similar properties in laboratory experiments to verify the results of her simulations.

"These swimmers will each contain an AI brain that will give them decision-making capabilities, so they can determine for themselves how to swim better alone, and how to swim better with three or five or 10 companions. It will also be interesting to see if their behavior changes if they are allowed to cooperate and share information."

For example, she says, a swimmer may move closer to its companion. As it does, it may determine that it's moving faster. So it moves ever closer. But suddenly, it slows down. It then decides to retreat back to the previous distance where it maintained optimal speed.

"As the SAMs swim, they are constantly interacting with the environment, running that algorithm, and recalculating where they are in that formation and how fast or how efficiently they are moving. The goal is to find the best strategy for the cluster to swim together in a manner that's both fast and efficient."

Ultimately, the long-term aim is to insert micron-size (or centimeter-size, if they're being inserted in larger vessels like those in the gastrointestinal tract) artificial swimmers into the body where they could travel through the veins to deliver, for example, targeted chemotherapy drugs, or to break up a blood clot without the need to thin a patient's blood. They could also assist otherwise normal, high-quality human sperm in fertility treatments.

"In those cases, the sperm has good genetics, but maybe its tail is compromised, and so the swimmers could push the sperm toward the egg," she says. "And that has been demonstrated by other researchers to work in a lab environment."

"THE GOAL IS TO FIND THE BEST STRATEGY FOR THE CLUSTER TO SWIM IN A MANNER THAT'S FAST AND EFFICIENT." —Ebru Demir

Demir says it's been gratifying to receive the CAREER award and learn that her work has earned approval from her peers. But what really drives her is the sense that her time in the lab has the potential to solve life-changing problems.

"As cliché as it sounds," she says, "I really do want to use engineering to help humanity."

HANNAH DAILEY:
Advancing orthopaedic diagnostics

PECASE recipient Hannah Dailey '02 '06G '09 PhD, an associate professor of mechanical engineering and mechanics, is among nearly 400 scientists and engineers selected by the Biden administration for this top-level honor. Recipients are employed or funded by one of 14 participating government agencies.

Established in 1996, the PECASE acknowledges the contributions scientists and engineers have made to the advancement of science, technology, education, and mathematics (STEM) education and to community service as demonstrated through scientific leadership, public education, and community outreach.

Dailey was nominated for her work developing a virtual mechanical test that can identify nonunions—a failure of broken bones to properly heal—early in the healing process. Nonunions occur in about 10 percent of shinbone fractures, and patients with such a diagnosis face higher rates of depression, opioid use, and addiction. Earlier detection would allow for timelier surgical intervention. Dailey received the NSF CAREER award in 2020.

"Professor Dailey's groundbreaking contributions at the intersection of mechanical engineering, biomedical engineering, computational science, and human health are an inspiration to students and faculty," says Stephen P. DeWeerth, professor and dean of the Rossin College. "The PECASE award underscores

Continued

the exceptional caliber of her work and the interdisciplinary research and innovation taking place at Lehigh."

For Dailey, the PECASE award is a highlight of a journey in engineering that began before her time as a Lehigh undergraduate, continued with a postdoc in Ireland, and brought her back to the Rossin College, where she now leads the Dailey Ortho Lab.

Her research group focuses on imaging-driven engineering approaches to clinical problems in orthopaedics and currently collaborates with surgeon-investigators in hospitals worldwide. Dailey has publications in *Journal of Biomechanics*, *Clinical Biomechanics*, *Journal of Orthopaedic Research*, *Injury*, and *JBJS*. She also serves as co-founder and chief scientific officer of OrthoXel, DAC, an orthopaedic device company that grew out of technology developed while she was a postdoctoral researcher at the Cork Institute of Technology from 2009 to 2012. Dailey earned her PhD, MS, and BS in mechanical engineering from Lehigh.

"I'm very grateful to the National Science Foundation for having supported my research, and to Lehigh for enabling me to pursue this vision," she says. "The faith and support of my department and the college of engineering make this work possible. It's an honor to receive this award and know that my research is considered impactful and a valuable contribution to the community."

Dailey developed a virtual mechanical test that can be used for early identification of nonunions in shinbone fractures.

"IT'S AN HONOR TO RECEIVE THIS AWARD AND KNOW THAT MY RESEARCH IS CONSIDERED IMPACTFUL." —Hannah Dailey

TOMAS GONZALEZ-FERNANDEZ:
Enhancing gene-editing technology

CRISPR is a powerful gene-editing tool that holds enormous potential for treating genetic diseases by allowing scientists to cut, replace, or delete mutations in DNA. It can also modify gene expression, temporarily amplifying or diminishing its effects. Yet, despite its promise, applying CRISPR (which is a reagent, or a substance that facilitates a reaction) in patients presents significant challenges.

"CRISPR is difficult to control when you want to do gene editing *in vivo*, or directly in the patient," says Tomas Gonzalez-Fernandez, an assistant professor of bioengineering. "In this case, it's typically administered as a systemic injection, meaning it circulates throughout the entire body and can have adverse effects on areas other than the target tissue. It's important to control where CRISPR goes, and when the CRISPR action takes place, so it doesn't cause problems elsewhere in the body."

Gonzalez-Fernandez received an NSF CAREER award for his research that will explore how combining CRISPR with biomaterials can make the technology both safer and more effective for therapeutic use.

Through laboratory experiments, Gonzalez-Fernandez and his team will investigate using hydrogels to help guide the technology to the appropriate target and dictate the timing of the CRISPR action—in other words, controlling where and when the therapy takes place. They will initially study what happens when the biomaterial and CRISPR first come in contact.

"We want to better understand that interplay, and how we can optimize biomaterial properties, such as charge and porosity, to better control CRISPR delivery," he says.

After that, they will examine how these encapsulated or functionalized materials interact with human cells.

"That's the higher level of complexity we need to understand," he says. "How does the interaction between these materials and cells influence the gene-editing efficiency of CRISPR?"

To date, says Gonzalez-Fernandez, there has been very little research into how biomaterials could enhance CRISPR delivery. As such, this will be one of the first studies to study how both biomaterial design parameters and cell interactions affect CRISPR efficiency.

The ultimate goal is to design safer, more efficient therapeutics that could someday treat genetic diseases, including cancer, sickle cell anemia, cystic fibrosis, Alzheimer's disease, Duchnene muscular dystrophy (DMD), and other chronic musculoskeletal disorders.

The FDA recently approved CRISPR to treat sickle cell disease, an inherited disorder that causes red blood cells to deform and block blood flow and can cause severe pain. The therapy was done *ex vivo*, or outside the body, and the modified cells were then implanted back into the patient.

"This was the first approved CRISPR therapy, and it was a huge success for sickle cell anemia," says Gonzalez-Fernandez. "But it was all done in the lab, which requires highly specialized facilities."

Gonzalez-Fernandez studies how hydrogels could better guide where and when CRISPR technology is employed within the body for more effective therapeutic use.

He notes, too, that a recent clinical trial in which CRISPR was injected directly into a patient with DMD through a viral delivery system resulted in a fatal immunological response.

"The challenge is how can we make this therapeutic safer?" he says. "My answer for that is to use biomaterials. They can help pave the way for more localized therapies."

The CAREER award is validation of that belief.

"It feels good to know that the scientific community appreciates the direction my lab is going in, and the type of science I want to do," he says.

Beyond the lab, he's also designing an outreach initiative to engage high school students through what he calls "CRISPR in a Box." With support from the CAREER award, he will design simple, hands-on experiments to demonstrate how CRISPR can edit genes in bacteria—demystifying the technology and sparking curiosity in the process.

Gonzalez-Fernandez also runs a channel on the video-sharing and social media platform YouTube. As part of the grant, he will leverage it to further explain engineering concepts of human physiology to increase public understanding of gene-editing technologies.

"Research has shown that people are against CRISPR, not because they're inherently afraid of it, but because they don't understand it. If we can better inform the public about what it is, and how we can make it safer and more efficient, we can ultimately increase acceptance of the technology."

"IF WE CAN BETTER INFORM THE PUBLIC ABOUT WHAT CRISPR IS, WE CAN INCREASE ACCEPTANCE OF THE TECHNOLOGY." —Tomas Gonzalez-Fernandez

A. EMRAH BAYRAK: Optimizing human-AI teams

Imagine a design team tackling the power train of an electric vehicle. Humans bring their expertise and intuition, while artificial intelligence crunches data and explores countless options. But how do you find the sweet spot where human ingenuity and AI work best together?

That's the question driving A. Emrah Bayrak, an assistant professor of mechanical engineering and mechanics, who is exploring the uncharted territory of human-AI collaboration in complex design. His research, supported by an NSF CAREER award, delves into how humans and AI can seamlessly divide and conquer design challenges.

Bayrak is developing models that predict how different people—from AI enthusiasts to skeptics—approach design, and how these individual preferences influence the ideal balance between human and machine. He's even putting his theories to the test, asking study participants to team up with artificial intelligence on virtual vehicle design projects.

The goal isn't to replace human designers, he says, but to create a road map for integrating AI in ways that boost both productivity and job satisfaction, ultimately shaping how teams of the future will operate.

A PATH FOR SHARED DISCOVERY

BY **CHRISTINE FENNESSY**

New program connects aspiring undergraduate researchers with PhD student mentors

Experiential learning is fundamental to Lehigh Engineering's mission—and a new addition to the Rossin College's catalog of hands-on opportunities puts a twist on undergraduate research.

The Rossin Research Scholars Program, launched in late 2024, pairs undergraduates with PhD students for a yearlong mentored research project, culminating in the expected publication of a journal and/or conference paper. It's a win-win: Authorship is a meaningful differentiator for undergrads as they consider their next steps, while the opportunity to design and lead research projects provides doctoral students with a valuable chance to test-drive a possible career path.

"Mentoring is teaching," says Mark Snyder, a professor of chemical and biomolecular engineering and the college's associate dean for graduate education. "You learn things best when you're teaching them. Leading students to a point where they feel comfortable tackling really challenging problems is a valuable experience."

Interested undergrads submit a brief application (prior research experience is not required) to Snyder and Derick Brown, a professor of civil and environmental engineering and the college's associate dean for undergraduate education, who together oversee the program. PhD students write a short proposal identifying a project related to their own research where they'd like to serve as mentors, and they review the undergraduates' applications to select their preferred mentees.

The Spring 2025 cohort is the program's first. Undergrads began the semester navigating the research "learning curve" in the lab. Over the summer, they will engage in full-time research and receive a stipend. In the fall semester, they will write up their work, contributing to a publication or an abstract and/or attending a conference. Graduate students participate in a workshop on mentoring and also receive funding they can direct toward their research.

"What's been so exciting to see is that this first group includes students with prior exposure to research and others who are eager but new to it," says Snyder. "We want both types of students in this program."

For the first cohort, Snyder and Brown received nearly 50 undergraduate applications along with proposals from 18 doctoral students, representing 15 faculty members.

One of those PhD students is bioengineer Hayley Whitney '24, a member of the lab led by Dhruv Seshadri, an assistanr professor of bioengineering. Whitney, who is in her first year of graduate studies, is exploring how integrating subjective health information with wearable devices can improve performance in athletes, specifically, in members of Lehigh's basketball, soccer, and football teams. The long-term vision, she says, is to develop AI-driven injury prevention and return-to-play strategies while providing insights for coaches.

It's a lot of work: She and her team monitor nearly 100 athletes, collect and analyze massive amounts of data, troubleshoot devices, and rise before dawn in the summer to observe practices. As soon as she heard about the new program, Whitney knew an aspiring researcher could learn much from her project and potentially take it in new directions. She saw just as much opportunity for her own growth.

"I've tutored my whole life, and I love, love, love, mentoring and teaching," says Whitney. "But doing those things in a lab setting is a new experience for me. I'm looking forward to learning how to provide students the right amount of guidance and space to figure out solutions on their own."

Through the Rossin Research Scholars Program, she's honing those skills while mentoring Kailey Miller '29, a first-year mechanical engineering student in the college's Bachelor's to Master's Accelerated Program. Miller came to Lehigh with research experience gained in high school working on an anti-tremor device for people with Parkinson's disease.

"When I got the email describing the program, I saw that it would allow me to spend my summer on campus and immerse myself in research," says Miller, who will be assisting in the design of innovative technologies to further validate athlete performance and identifying key biomarkers associated with allostatic load, the wear and tear on the body caused by cumulative stressors. "Being partnered with a PhD student was important to me because that's the track I want to go on as well. And Hayley is amazing—she introduced me to the whole lab, showed me how to work all the equipment, and answered all of my questions. I've learned so much from her already."

That kind of impact underscores the value of hands-on learning, says Stephen P. DeWeerth, Rossin College professor and dean, who has made expanding experiential learning a cornerstone of his tenure—as well as a pillar of the new First-Year Rossin Experience (FYRE) that is currently in development. "We believe it's critically important that all students engage outside of their formal learning in ways that help them explore their passions, define their identities, and chart a path toward meaningful, fulfilling careers."

Whitney (right) mentors Miller in using infrared imaging to track biomarkers for heart rate analysis and improved image processing.

PHOTOS BY CHRISTA NEU

NEW HUB FOR ROBOTICS

The Freed Family Robotics Design Studio in Wilbur Powerhouse is Lehigh's latest Design Lab and a space where students can bring their ideas to life.

The studio, which was made possible through a donation from metallurgy and materials engineering alumnus and university trustee Drew Freed '83 '17P, was dedicated in February.

"The Freed Family Robotics Design Studio came out of our question of, 'What's next?'" says Stephen P. DeWeerth, Rossin College professor and dean. "With the Design Labs, the goal is to have tools there so students can be creative and develop designs to respond to their ideas," DeWeerth says. "They can be makers, and making is a central part of our university strategy."

The robotics studio works in conjunction with the Electronics Design Studio, which opened in 2023 and provides students with supplies to create circuitry. Students who want to make something more complex that involves motion, the ability to react to an environment, or even the capability to make decisions would visit the robotics studio.

Robotics has become a popular area of study at Lehigh in recent years. The Autonomous and Intelligent Robotics Lab (AIR Lab) opened at the Mountaintop Campus in 2021, and there are numerous active student clubs, including the Lehigh Alliance of BattleBots (members pictured above), Lehigh Aerial Swarms Club, Lehigh University Space Initiative, and Lehigh Underwater Robotics. The studio will serve as the new hub for clubs and provide a space for undergraduates, regardless their level of experience, to explore robotics.

"The Design Labs play this amazing role of resourcing all these different kinds of projects, from complex game-changing robotics research, to a student wanting to build a small device that does something interesting," DeWeerth says. "You have this whole range where they provide space, they provide materials and supplies, and most important, they provide advice, guidance, and mentoring." *—Christina Tatu*

ROBOTICS AT LEHIGH

With new spaces, innovative projects, and interdisciplinary collaboration, robotics is on the rise at Lehigh. Scan the code to learn more.

Sun has recently shared insights on AI in campus talks hosted by Lehigh's Institute for Data, Intelligent Systems, and Computation (I-DISC).

Finding harmony in the age of artificial intelligence

Lichao Sun tackles the privacy and trust challenges of generative AI, from safeguarding music to improving medical decision-making

No matter what time of day you read this story, it's a near certainty that you've come in contact with artificial intelligence at some point since rolling out of bed. AI is on our phones and in our cars. It's sounding off in any number of rooms in our houses, where we work, and where we play. Such ubiquity is ripe for misappropriation.

"Over the past five years or so, AI technology has developed to the point where nearly all of us interact with it on a daily basis," says Lichao Sun, an assistant professor of computer science and engineering. "But with that level of development, there comes significant issues around trustworthiness, privacy, and security. As a field, we're way behind in addressing those concerns."

Sun has devoted his career to tackling security and privacy challenges related to AI technology. One of his current projects confronts the persistent problem of protecting online audio content from being appropriated to train generative AI models, including large language models (LLMs) such as ChatGPT and DeepSeek, and diffusion models such as Dall-E and Sora.

"When these models collect audio that is not protected, it can create a host of problems for the creator of that data," says Sun. "For example, it can infringe on their copyright protections and cause them to lose out on revenue, or the data can be used to create false or misleading information like when the speaker's voice is appropriated to endorse something or someone they do not personally believe in, or to do something nefarious."

Sun and his team are collaborating with researchers at the University of Tennessee to develop a framework that will make audio content—specifically music in this case—"unlearnable" by AI. Called HarmonyCloak, the approach essentially introduces white noise, or perturbations, that are imperceptible to the human ear. The additions don't affect fidelity, but they make the music incomprehensible to AI models.

"It gives the content creator control over how their work is used," he says. "If a tech company wants to use that music to train their model, the company has to pay for it. Once they've paid for it, the creator can strip out that protective layer."

The team, which includes Syed Irfan Ali Meerza, a PhD student, and Jian Liu, an assistant professor of electrical engineering and computer science, both from UT Knoxville, has shown that HarmonyCloak can effectively shield music across a range of commonly used AI models. Since such technology is constantly evolving, the group is working on developing a universal perturbation that can work across any model.

The ultimate goal, says Sun, is to develop a plug-in of sorts that creators can deploy within their music before it's published online.

> "AS A FIELD, WE'RE WAY BEHIND IN ADDRESSING CONCERNS ABOUT AI."
>
> —Lichao Sun

Sun's other projects include developing a benchmark called TrustLLM that can evaluate the trustworthiness of large language models around toxicity, bias, and value-alignment inherent in the LLM. (Value-alignment refers to matching, generally, human values.)

The effort seeks to improve our understanding of how conversation generation models perform and to help guide the technology to advance following a more ethical and socially responsible path. Essentially, the benchmark evaluates the safety, security, and privacy issues of generative AI, especially large language models.

He is also working on an open-source, vision-language foundation model called BiomedGPT that can perform medical tasks. This model may one day help doctors by interpreting complex medical images, assist researchers by analyzing scientific literature, or even aid in drug discovery by predicting how molecules behave.

"This work combines two types of AI into a decision-support tool for medical providers," says Sun, who is the lead author of a paper recently published in the prestigious journal *Nature Medicine* detailing the approach. "One side of the system is trained to understand biomedical images, and one is trained to understand and assess biomedical text. The combination of these allows the model to tackle a wide range of biomedical challenges, using insight gleaned from databases of biomedical imagery and from the analysis and synthesis of scientific and medical research reports."

All three projects involve Sun's PhD students and extensive collaboration with other universities, and, in the case of BiomedGPT, other Lehigh faculty and medical institutions including Massachusetts General Hospital, which validated the model's effectiveness and applicability in real-world healthcare settings.

"I really enjoy these collaborations," says Sun. "These problems are so complex and require expertise across a wide range of areas. Working together, we have a real opportunity to make meaningful contributions when it comes to privacy, security, trustworthiness, and the potential of AI."

What does 'GPT' mean? GPT stands for "generative pre-trained transformer." It's a type of AI model designed to understand and generate human-like text. GPT models are pre-trained on vast amounts of data and use advanced algorithms to predict and create coherent responses, making them powerful tools for tasks like language translation, conversational AI, and text analysis.

MOOSEDJADOBE STOCK

FUELING FUTURE MAKERS

The Rossin College is committed to ensuring that every engineering student, regardless of their circumstances, has the chance to engage in transformative, hands-on learning. Here, education extends beyond the classroom.

Our students design, build, innovate, and solve real-world problems. They bring ideas to life in labs and makerspaces, compete on high-stakes teams, contribute to groundbreaking research, and follow their passions. These dynamic experiences equip them with the lifelong skills needed to lead in a complex world.

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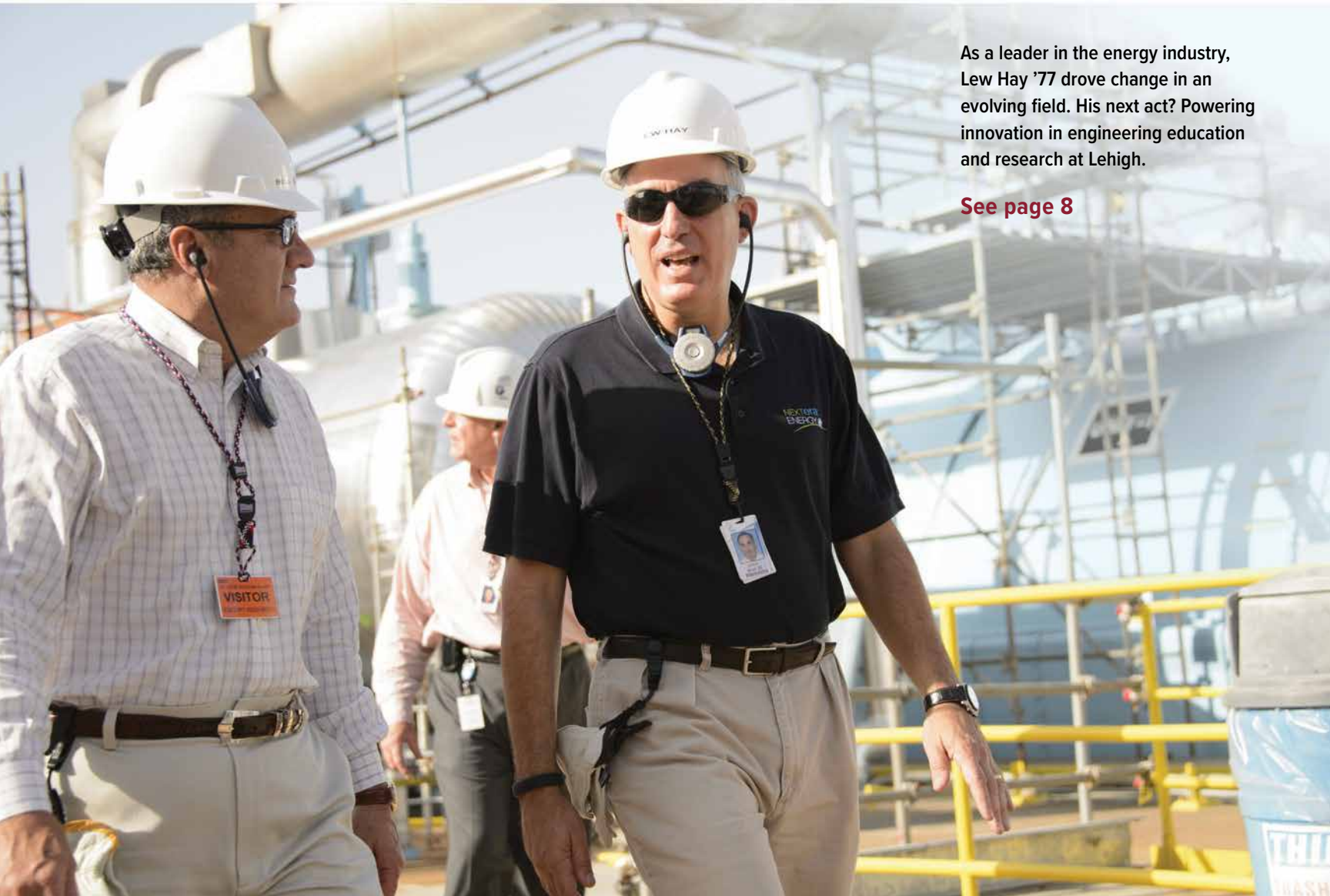

As a leader in the energy industry, Lew Hay '77 drove change in an evolving field. His next act? Powering innovation in engineering education and research at Lehigh.

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