Spring 2023

/resolve®

Engineering Innovation @LehighU

SEEING THE BIG PICTURE

Experts across engineering and social sciences converge to tackle grand challenges

See page 10

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

Features

Departments

Research Briefs

/resolve® Spring 2023
Engineering Innovation @LehighU

COLLEGE DEANS
Stephen DeWeerth
Professor and Dean

John Coulter
Professor and Sr. Associate Dean
for Research and Operations

Sabrina Jedlicka
Associate Professor and Associate Dean
for Academic Affairs

Kristen Jellison
Professor and Associate Dean
for Faculty Development

Susan Perry
Professor of Practice and Assistant Dean
for Academic Affairs

PUBLICATION DIRECTOR | Chris Larkin

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
Emily Collins, Lori Friedman, Carina Sitkus

COVER CREDITS
Front: Sarah Hanson
Back: Christa Neu

RESOLVE® is published semiannually by the P.C. Rossin College of Engineering and Applied Science.

engineering.lehigh.edu/resolve

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

OPPOSITE PAGE: DOUGLAS BENEDICT/ACADEMIC IMAGE

LETTER FROM THE DEAN

Bridging disciplines, connecting communities

Welcome to the Spring 2023 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 of *Resolve* is dedicated to efforts that connect disciplines, and entire communities, in pursuit of common goals that are grounded in equity and sustainability. In particular, several emerging research initiatives on our campus underline Lehigh's ability to contribute to scientific and technological discovery by bridging disciplines in novel ways to bring about real, lasting, consequential change.

This concept of convergence research animates the broader scientific community these days, as well. Convergence research is use-inspired scientific exploration driven by a specific problem or societal need that gathers an intellectually diverse set of experts to address a pivotal issue from all angles.

Global challenges that require this approach dominate news headlines: Think population health, sustainable energy, climate change, and the impact of online misinformation, for example. Sponsor agencies such as the National Science Foundation (NSF) increasingly prioritize convergence-driven projects in their solicitation efforts.

Convergence calls for interdisciplinary team science, and Lehigh is hardwired for endeavors of this nature. After all, applied, boundary-dissolving research and education is the very foundation of our institution. Examples abound across our educational programs, the achievements of our alumni, and the research agendas of our faculty.

Since their inception, Lehigh's Interdisciplinary Research Institutes (IRIs) have been a clear manifestation of our community's convergence research mindset in action. They have nurtured discovery in areas such as infrastructure design and socioeconomics, materials science and health, and human-centered computing, to name a few. The IRIs encourage partnership that exposes us to new ways of thinking about our work as engineers, thereby throwing into sharp relief the human impact of that work.

Read on to learn about a new partnership arising from the IRIs that brings together researchers from the Rossin College, the College of Arts and Sciences, and the Institute for Indigenous Studies within Lehigh's College of Health (page 10). The collaboration cuts across engineering, biology, data science, cognitive psychology, and population health in a groundbreaking effort to prevent the *next* pandemic among some of society's most vulnerable groups.

Another emerging research partnership, this one among experts in computer science and journalism, seeks to better understand the power of social media in framing individuals' beliefs and influencing their actions. It's a fascinating exploration of how technology shapes cognition, emotion, and behavior.

LEHIGH'S **INTERDISCIPLINARY RESEARCH INSTITUTES** ARE A CLEAR MANIFESTATION OF OUR COMMUNITY'S **CONVERGENCE RESEARCH MINDSET** IN ACTION.

This issue also highlights a string of winning bids to land Major Research Instrumentation support from the NSF (page 20). The secret to our considerable success rate in these proposals is, in fact, not so secret: Scores of faculty, hailing from a range of disciplines across Lehigh's IRIs, joined forces to prove how broadly these grants could be leveraged across our research community and beyond.

On page 16, we introduce three new faculty in the Department of Civil and Environmental Engineering whose arrival on campus is another clear indication of Lehigh's convergence mindset. Professors Farrah Moazeni, Gabrielle String (who holds a dual appointment in the College of Health), and Maryam Rahnemoonfar (who holds a dual appointment in computer science and engineering) bring with them innovative, outward-looking data-driven research. They draw upon expertise in artificial intelligence, smart devices and systems, and humanitarian engineering to address sustainability challenges involving water, energy, and infrastructure, and the associated social impact. Importantly, they also help to bring the department faculty's gender balance into alignment with that of its students—an achievement in equity and inclusion that strengthens our research portfolio and our mentorship of the next generation of Lehigh engineers.

We also check in with Svetlana Tatic-Lucic (page 8), a Rossin College faculty member currently serving a stint as a program director with the NSF. In this capacity, she oversees efforts to support interdisciplinary science and engineering research sponsorship in the area of sensing and biomedical applications. Svetlana describes how her experience at Lehigh prepared her to tackle this important role.

Thank you as always for your interest in Lehigh Engineering and the Rossin College. Please drop me a note with your comments.

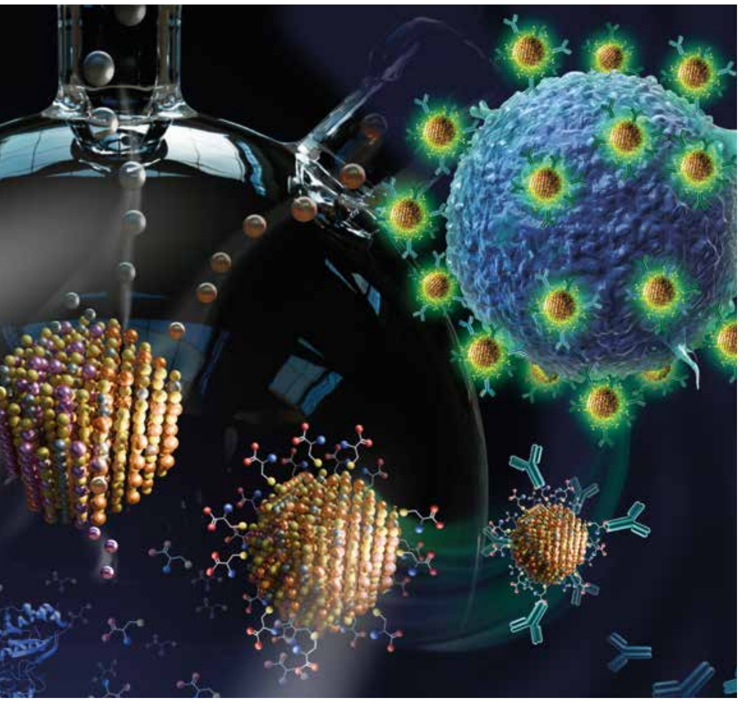
Stephen P. DeWeerth, *Professor and Dean*
P.C. Rossin College of Engineering and Applied Science
steve.deweerth@lehigh.edu

Unraveling the complexities of quantum dot synthesis

Research team uses low temperatures and water to create functional particles

Quantum dots are nanoscale crystalline particles that act as semiconductors. When exposed to UV light, they emit energy in the form of light, and the size of the quantum dot determines the color it emits.

"So by tuning the particle's size, you can essentially tune its optical properties," says Mark Snyder, an associate professor of chemical and biomolecular engineering (ChBE), "which makes them interesting materials to use in applications like bioimaging."



In a paper published in the *Journal of Materials Chemistry B*, Lehigh researchers outlined a greener, more scalable way to create quantum dots.

The problem, however, is that quantum dots are typically synthesized using toxic solvents, high temperatures, and hot injection methods. "All of which create challenges from the standpoint of sustainability and scalability," says Snyder.

To overcome those challenges, researchers seek to create high-quality, nontoxic, functional quantum dots via green, scalable synthesis routes.

Snyder and his team recently published a paper in the *Journal of Materials Chemistry B* that outlines just such a synthesis method. The project was funded by the NSF's Scalable Nanomanufacturing program, and was a collaborative effort among labs led by Snyder, ChBE department chair Steven McIntosh, and Harold B. Chambers Senior Professor in Materials Science and Engineering Christopher Kiely. The lead author is Nur Ozdemir '22 PhD, a recently graduated member of Snyder's lab.

Earlier work by McIntosh, Kiely, and the University of Virginia's Bryan Berger had explored a biomineralization-based approach to synthesize quantum dots using low temperatures and aqueous conditions. Biomineralization is the process by which biological systems produce inorganic materials.

"The question that Nur was addressing with this paper was how to use biomineralization to synthesize quantum dots with greener and tunable compositions," says Snyder. "She was able to show that she could do this in 'one pot,' meaning, she could grow high-quality particles with tailored composition in a single vessel. And under these aqueous conditions, the particles themselves are hydrophilic, so they can be used directly in aqueous applications without any complex purification steps. And they're also easily functionalized—in this particular case, with antibodies that were specific to certain cellular systems."

For this application, Ozdemir collaborated with co-author Shannon Collins '21 PhD, who at the time was researching antibiotic resistance with Lehigh ChBE associate professor Angela Brown.

"I think this paper is an excellent example of student-driven research," says Brown, who is also one of the paper's authors. "I think it was over lunch one day that Nur was talking to Shannon about wanting to show that these quantum dots could be used for targeted imaging, and Shannon was able to help her do that."

Brown says that, together, the students were able to show proof of concept. The quantum dots, functionalized with an antibody, could successfully target receptors for that antibody on specific cells.

"What's so interesting about the quantum dots is that they can be made to emit different colors," she says. "And so, in theory, you could look at multiple things on a cell, such as the presence or absence of a specific protein associated with disease or the distance between two different proteins to provide information about how those proteins interact with each other. So there's a lot of possibilities there in terms of identifying what's going on with the cell—is it healthy, is it dying, is it changing in some way?"

> "QUANTUM DOTS CAN EMIT COLORS, SO, IN THEORY, IT'S POSSIBLE TO IDENTIFY WHAT'S GOING ON WITH THE CELL. IS IT HEALTHY? DYING?"
>
> —Angela Brown

The synthesis process, too, opens a number of doors.

"Even though we looked at silver indium sulfide with zinc incorporation, the approach should be applicable to a whole range of other compositions in the metal sulfide class of materials," says Snyder. "A broader materials palette could potentially now be accessible because of the work that's been done here to unravel some of the complexities in the biomineralization system."

LEFT: NICOLLE R. FULLER/SAYO STUDIO; BOTTOM: ISTOCK/YUOAK

TOP: STEPHANIE VETO; BOTTOM: ISTOCK/DON WHITE

A 'holistic approach' to predicting Ebola outbreaks

Several years ago, a Lehigh team developed a predictive model to accurately forecast Ebola outbreaks based on climate-driven bat migration. Ebola is a serious and sometimes deadly infectious disease that is zoonotic, or enters a human population via interaction with animals. It is widely believed that the source of the 2014 Ebola outbreak in West Africa, which killed more than 11,000 people, was human interaction with bats.

Now members of the team have examined how social and economic factors, such as level of education and general knowledge of Ebola, might contribute to "high-risk behaviors" that may bring individuals into contact with potentially infected animals. A focus on geographical locations with high concentrations of individuals at high risk could help public health officials better target prevention and education resources.

Students traveled to Sierra Leone to collect data for the project while participating in Lehigh's Global Social Impact Fellowship program.

"We created a survey that combined the collection of social, demographic, and economic data with questions related to general knowledge of Ebola transmission and potentially high-risk behaviors," says Paolo Bocchini, a professor of civil and environmental engineering and one of the study's leaders. "Our results show that it is indeed possible to calibrate a model to predict, with a reasonable level of accuracy, the propensity of an individual to engage in high-risk behaviors."

The results were detailed in a paper published last year in *PLOS ONE*. Additional authors include Lehigh doctoral student Sena Mursel; recent graduates Nathaniel Alter '22, Lindsay Slavit '20 '21, and Anna Smith '22; and Javier Buceta, a faculty member at the Institute for Integrative Systems Biology in Valencia, Spain.

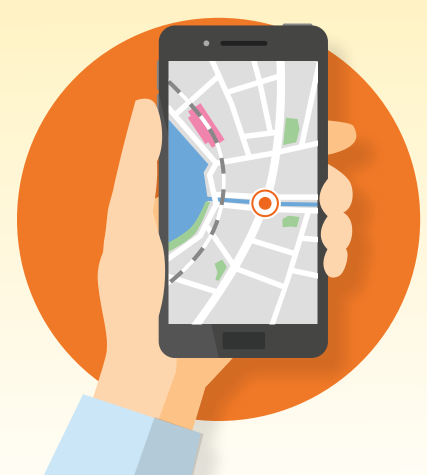
The authors say their results point to the need for a holistic approach for any model seeking to accurately predict disease outbreaks. Their findings may also be useful for population health officials, who may be able to use such models to better focus scarce resources.

"One has to look at the big picture," says Bocchini. "We collected satellite images that showed the evolution of enviro-climatic data and combined them with ecological models and random field models to capture the spatial and temporal fluctuations of natural resources and the resulting continent-wide migrations of infected animal carriers. We also studied the human population's social, economic, demographic, and behavioral characteristics, integrating everything to obtain our predictions."

Only this "broad perspective and interdisciplinary approach can truly capture these dynamics," says Bocchini. "And with this line of research, we are proving that it works."

To collect data, Bocchini and Buceta traveled to Sierra Leone with a delegation of undergraduate students from Lehigh with support from the National Institutes of Health and Lehigh's Office of Creative Inquiry and in collaboration with nonprofit World Hope International.

SMARTPHONE DATA COULD DRIVE INNOVATION IN BRIDGE HEALTH MONITORING



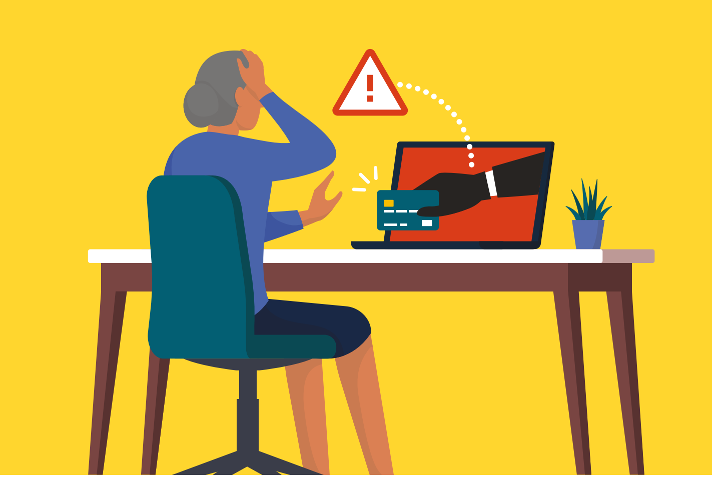
Your phone already has an app that can tally your daily steps and log your maximum heart rate, but structural engineers have another type of wellness tracker—one that monitors the health of bridges—in mind.

A research team, including Shamim Pakzad, professor and chair of Lehigh's Department of Civil and Environmental Engineering, has demonstrated that GPS and accelerometer data collected from smartphones can be used to accurately detect modal frequencies from bridges. These vibrations can be used to assess the condition of spans but are typically collected via special, fixed sensors attached to the bridges themselves.

In a paper recently published in *Communications Engineering* (a *Nature* publication), the researchers examined data collected from their own phones in vehicles driven over the Golden Gate Bridge in San Francisco and a shorter concrete bridge in Italy, as well as data crowdsourced from Uber drivers. In all three cases, the readings matched up closely with data gathered from the more sophisticated—and costly—stationary sensors.

While biennial visual inspections are still required by code for assessing bridge health, crowdsensing and mobile sensors (which Pakzad has been studying for more than a decade) could prove to be valuable, cost-saving tools to keep bridges safe, functional, and in service for longer periods. They could also help allocate resources for maintenance and management to the most critical areas.

The lead author is Thomas Matarazzo '12G '15 PhD, an assistant professor at the U.S. Military Academy at West Point. Soheil S. Eshkevari '20 PhD, now a senior machine learning engineer with Uber, is also a co-author. Both were advised by Pakzad at Lehigh.



Designing a digital platform to make seniors savvy to online scams

Data from the FBI's Internet Crime Complaint Center shows that in 2021, more than 92,000 U.S. adults aged 60 and over reported being victims of online scams. Their losses? Roughly $1.7 billion.

To confront this problem, researchers from Lehigh and four other universities have been granted a two-year, $5 million National Science Foundation award to create digital tools that help older adults better recognize and protect themselves from online deceptions and other forms of disinformation.

"Senior citizens are one of the most targeted and vulnerable groups when it comes to social financial scams," explains Dominic DiFranzo, an assistant professor of computer science and engineering.

DiFranzo is a collaborator on the Deception Awareness and Resilience Training (DART) project, which is led by University of Buffalo professor Siwei Lyu, through UB's Center for Information Integrity. The team also includes members from Cornell University, Clemson University, and the University of Illinois Urbana-Champaign.

The project is funded by the NSF's Convergence Accelerator, a program the agency launched in 2019 to support "basic research and discovery to accelerate solutions toward societal impact."

DART builds upon a $750,000 Phase I grant the multi-university research team received in 2021, when it began meeting with older adults in Western New York and South Carolina to better understand why they fall victim to online deceptions.

The approach uses digital games—including engaging and realistic social media situations—to make learning fun. The aim is to make DART easy to use, so older adults can learn on their own, in communal settings such as adult homes or libraries, or with the aid of a caregiver.

There are many digital literacy tools available, but many are not tailored to older adults, which limits their effectiveness. DART aims to address this limitation by including a wide range of online schemes older adults encounter. The team will update the learning materials as schemes evolve.

Lehigh is leading the technical design, development, and deployment of the DART platform.

Passing the stiff(ness) test

New technique could help researchers more accurately replicate human tissue with hydrogels

Hydrogels—networks of highly absorbent polymer chains—play a key role in the development of cutting-edge implantable devices for wound healing. When a hydrogel scaffold is encapsulated with stem cells and injected into an injury site, the cells can migrate to the damaged area and accelerate healing. Designing an effective material for this emerging technique, however, requires closely matching the properties of the implant to that of the native tissue.

"If you want to repair something like the ACL, which tends to have a really steep change in stiffness as you move from the center of the tendon out toward the bone, you need a material that also exhibits that strong change in stiffness," says John McGlynn '22 PhD, who recently graduated and is now at Merck.

McGlynn—together with his advisor and co-author Kelly Schultz, an associate professor of chemical and biomolecular engineering—developed a method that will help researchers better quantify the stiffness of nonuniform hydrogels and, therefore, better match the properties of human tissue. That method is described in a paper recently published in *Macromolecules*, with McGlynn as lead author.

"In our lab, we hadn't investigated materials with nonuniform stiffness," he says. "We wanted to see what the impact of these changes in stiffness had on the migration and motility of cells encapsulated in the network."

While hydrogels with a stiffness gradient can better mimic native tissue, he says, they can also yield better control over certain aspects of the stem cell, such as its shape, its rate of migration, and its lineage specification, which determines what type of cell it will become.

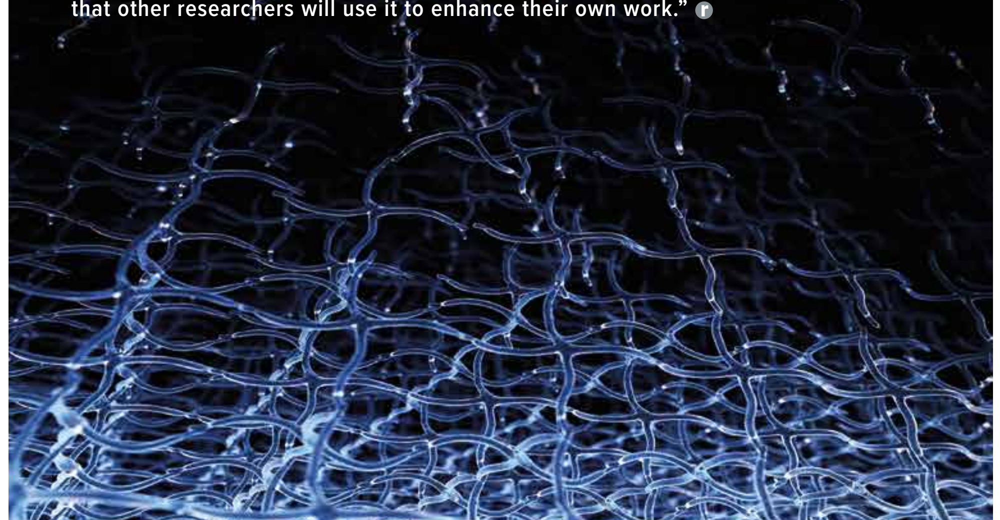
"If you can precisely control the changes in the stiffness of the material, you could better control cell behavior, which could translate into more controlled cell delivery and better wound repair," he says.

The method he devised to quantify stiffness involves using ultraviolet (UV) light exposure. By varying the degree of UV light intensity across regions of the hydrogel, he could change the extent of reaction, or the degree by which polymers cross-linked, causing the region to autofluoresce. The brighter the region, the stiffer the material. McGlynn says that brightness is likely due to a phenomenon called aggregation-induced emission. He says this no-touch technique of measuring stiffness is an improvement upon a common method called atomic force microscopy, which involves applying a force to the hydrogel and measuring its response.

"That technique can actually damage the native structure, and there are other assumptions involved with it that can invalidate your measurements," he says.

For researchers focused on improving the design of implantable devices that will help patients heal faster with less pain, this new method is yet another important step forward. And it isn't limited to the medical field.

"There's a huge library of hydrogels, with applications in areas like cultured meat, and this technique is applicable to many of them," says McGlynn. "We hope that other researchers will use it to enhance their own work."



Paving the way toward a fusion pilot plant

For the past 20 years, Eugenio Schuster, a professor of mechanical engineering and mechanics, has been part of an international team of scientists and engineers working at tokamaks, nuclear fusion reactors designed not to produce energy, but to help researchers study the physics of the plasma.

Their ultimate goal is to ensure the reality of sustained fusion—and the success of ITER, the world's largest nuclear fusion reactor, which is being built in France. The machine is the product of an international effort to essentially harness the energy-generating power of the sun.

Schuster leads a Lehigh team that recently received nearly $1.75 million from the Department of Energy (DOE) to continue their work in support of ITER and to help the United States establish its own nuclear fusion reactor within the next decade. The award is part of a $47 million effort the DOE announced this past October to fund research aimed at closing the gap in science and technology when it comes to nuclear fusion.

Current tokamaks work in what's called a pulsed regime, but they're not created equal, says Schuster. Unlike the newer machines in South Korea (KSTAR) and China (EAST), those in the U.S. lack the superconducting coils necessary for extended operation.

"So, for example," he says, "with the DIII-D tokamak in San Diego, the pulse is around six seconds long. So we run an experiment for six seconds, and then we have to wait for the machine to cool down before we can run another one."

KSTAR and EAST are known as long-pulse machines, and can run on the order of hundreds of seconds, which makes them ideal for experimentation that could eventually be applied to ITER (which is also designed for long-pulse and eventual steady-state operation). Ultimately, says Schuster, for nuclear fusion to be economically feasible, future reactors will have to operate in very long pulses (in comparison to the time between pulses) or in steady state.

Part of Lehigh's DOE award will support research at KSTAR, where Schuster's Plasma Control Group—together with teams from General Atomics, Oak Ridge National Laboratory, and Princeton Plasma Physics Laboratory (PPPL)—will address critical research questions related to the development of ITER's long-pulse scenarios and their active control. The remainder will fund research that Schuster's group will do at EAST. One of the goals of that project, which includes teams from General Atomics, Lawrence Livermore National Laboratory, MIT, PPPL, and UCLA, is to guide the design of a fusion pilot plant (FPP) in the United States.

"DOE asked the National Academies of Sciences, Engineering, and Medicine to determine what was needed here in the U.S. to really advance nuclear fusion, and in particular, to bring fusion energy to the grid," says Schuster. "One recommendation was the construction of a fusion pilot plant. That's why the DOE is funding American researchers to do this work abroad. It will help us learn from these superconducting tokamak machines so that eventually, we can build a long-pulse reactor-degree device here."

Schuster says the goal is to design, develop, and begin producing energy within 10 years.

"It's a very aggressive timeline," he says. Indeed, especially considering that ITER—with its 16-year head start—is not yet operational. The difference, Schuster says, comes down to investment and technology.

"If you want to make things faster, you need to invest more heavily," he says. "In the past, investors in nuclear fusion were exclusively governments, which are often constrained by budgets aligned with shorter-term priorities. But now, you have startup companies funded by billionaires, and they aren't constrained in the same way. The DOE is presently developing partnerships with private investors to accelerate the development of fusion energy."

The technological constraints have also changed dramatically. Developments in computational power and advancements in superconducting coils capable of generating ever stronger magnetic fields to contain the plasma have pushed the field forward, faster.

"We now have the capability to better predict the evolution of the plasma, thanks to more powerful computational resources, to understand the physics of the plasma more precisely after decades of studies, and to process the huge amount of data that comes from plasma experiments so that we can better learn from these experimental results," he says. "So we do believe that we're in a position to design and build this FPP much faster than we did with ITER."

The promise of nuclear fusion is a big one: If achieved, it could provide a limitless supply of clean, safe, and reliable energy. And now, with the force of American entrepreneurship behind it, the efforts of Schuster, and so many researchers like him, may finally be realized.

"This fusion pilot plant is what we've all been working on and waiting our whole lives for," he says. "It's the opportunity to develop a type of energy that comes with so many benefits in terms of pollution, climate change, and fuel security—right here at home."

Above: Schuster in ITER's Assembly Hall. Inset: The on-site production facility for superconducting coils.

Advancing neurostimulation beyond the pacemaker

In a pharmaceutical approach to disease treatment, blood transports drugs throughout the entire body, sometimes producing undesirable side effects. Electroceutical or bioelectronic therapy offers a more selectively targeted approach, leveraging the electrical impulses that regulate the body's functions through the nervous system, with the goal of affecting only the organ of focus.

The research seeks to understand what nerve stimulation does to an organ, says Kothare, and develop predictive mathematical models of this behavior to help develop treatments.

Electroceuticals are not new. The pacemaker, which sends electrical signals to stabilize heart rhythms, was invented in the 1950s. However, nerve stimulation is not yet broadly approved to treat other diseases. Vagus nerve stimulation devices, for instance, have only been approved by the FDA to treat epilepsy and depression.

Mayuresh Kothare, the R. L. McCann Professor of Chemical and Biomolecular Engineering, and his colleagues are investigating how the neurostimulation of peripheral nerves—the nerves located near various organs—could be used to treat other diseases, just as pacemakers are commonly used to help regulate heart function. With approximately $2.2 million from the National Institutes of Health (NIH) through the Simulating Peripheral Activity to Relieve Conditions (SPARC) program, the team is developing software and modeling tools for optimizing the delivery of neurostimulation signals to peripheral nerves to treat conditions such as cardiac arrhythmia, hypertension, and stomach and bladder disorders. Little research exists on the use of electroceuticals to treat such disorders.

"Nerves connect different organs," Kothare explains. "There is a nerve connecting to the heart, there is a nerve connecting to the stomach, and there is a nerve connecting to the bladder. So those nerves are the ones that control the function of each organ. We are looking at typical diseases that affect [the heart and stomach]. We are trying to develop techniques, combining engineering and experimental approaches, that would allow us to treat those diseases through neural stimulation."

The team is working to determine how to generate the correct response to effectively treat the right problem, Kothare says. In the case of a pacemaker, wires are implanted in the heart and connected to an implanted chip so the pace of the heartbeat can be monitored and adjusted, if necessary, through the delivery of electrical energy. Similarly, Kothare says, common disorders of the stomach, such as constipation or irregular rhythms of the stomach that cause chronic indigestion, could theoretically be treated by stimulating the gastric nerve, thereby changing the contractions of the muscles of the stomach.

"The grand challenge is how do you design these electrical signals so that they do what you want them to do?" he says. "Because if you send the wrong neural signal, it could create a worse symptom. Just like with drugs—a drug can have a good effect or a bad effect."

Kothare and Babak Mahmoudi, a machine learning scholar from Emory University, lead the project. Collaborators include Charles Horn, a neuroscientist from the University of Pittsburgh; Raj Vadigepalli, a professor of pathology, cell biology, and anatomy from Thomas Jefferson University; and Gautam Kumar '08G '13 PhD, an assistant professor of chemical and materials engineering at San Jose State University. Mark Arnold, a retired Lehigh computer science faculty member, helped develop novel approaches to software and cloud-based simulations for the project. Students and postdocs from across the institutions are also collaborating on the work.

The group is using a two-pronged approach. Horn is collecting experimental data by implanting electrodes in the gastrointestinal system of ferrets to stimulate the gastric nervous systems. Team members are also analyzing existing data, such as cardiac rhythm data collected from dogs by UCLA, which is where the modeling, machine learning, and cloud computing pieces come in.

"What we are trying to do is to develop mathematical models of the behavior of the organ in response to different stimuli, and then use these mathematical models to develop the best or 'optimal' signal that could eliminate the disorder," Kothare explains. "So that requires us to have an understanding of the underlying biophysics. How do the muscles contract? How does the contraction of the muscle move the liquid inside the stomach? What prevents the liquid from flowing out of the stomach continuously? These are the kinds of quantitative, almost engineering-like questions we are asking to understand in the form of equations and models—how we can predict the behavior of organs in response to stimulation. When we don't fully understand the underlying biophysics, we employ data-driven machine learning models to capture the observed behaviors."

This story was adapted from the *Lehigh Research Review (2022 Volume No. 7).*

RAYMOND BIESINGER (2)

TOP: ISTOCK/TRAIMAK_IVAN; CENTER: THE REMADE INSTITUTE LOGO IS A REGISTERED TRADEMARK OF SUSTAINABLE MANUFACTURING INNOVATION ALLIANCE CORP.; RIGHT: SHUTTERSTOCK/ANTONOV ROMAN

Making a dent in manufacturing emissions through materials optimization

While the jury is still out on the effectiveness of plastics recycling, the story with aluminum is generally regarded as a success. The material is "infinitely recyclable," meaning it can go through the process over and over, and doing so requires just a small fraction—an estimated 5 percent—of the energy it takes to produce aluminum directly from mined ore.

But recycling isn't the end-all: Actually reducing the amount of primary aluminum that manufacturers of vehicles and aircraft, electrical components, construction materials, and other goods demand would further cut fossil-fuel emissions and avoid the negative environmental impacts of mining.

It's a job for materials optimization and one that researchers at Lehigh are ready to tackle through a new project funded by the REMADE Institute.

"The objective of our project is to optimize the existing technological process, such as aluminum extrusion, that cannot be completely eliminated or replaced by another process," says Wojciech Z. Misiolek, chair of the Department of Materials Science and Engineering and Loewy Professor of Materials Forming and Processing. "A better understanding of the technological process and material response to the processing parameters will allow better process design for high-quality products with a minimized amount of metal scrap."

Misiolek, who is an expert in metals processing and directs Lehigh's Loewy Institute, led the university's effort to join REMADE last year. This large-scale partnership brings together industry, academic institutions, and national labs to help reduce manufacturing emissions and transition the U.S. to a circular economy.

A circular economy, according to the EPA, "reduces material use, redesigns materials, products, and services to be less resource intensive, and recaptures 'waste' as a resource to manufacture new materials and products." This systems-based approach is seen as a way to tackle large, global challenges including climate change and pollution.

REMADE, which was founded in 2017 and now has more than 150 members, seeks to develop new methods and reduce the costs of technologies that will enable manufacturers to design and implement transformative systems that will underpin a circular economy.

"The extensive background and experience of the Loewy Institute in conducting industrial process optimization studies using physical and numerical simulations put us in a well-aligned position to form a research team with industrial and academic partners," says Misiolek.

The project team also includes collaborators from fellow institute members Secat, the University of Kentucky, Gordon Aluminum Industries, and Castool Tooling Systems. Their goal is "to reduce scrap and consumption of primary aluminum during the manufacturing of thick-walled hollow extrusions by developing simulation tools for predicting the quality of seam and charge welds," according to the project description.

"We will develop computational methods and acceptance criteria for simulating the extrusion process," Misiolek says. "With these innovative tools based on the physical characterization of the material, we will be able to design process and die modifications to reduce the amount of scrap produced."

CLEAN ENERGY—WITH A DOSE OF REALITY

A Rossin College team is playing a key role in a multi-institution Energy Frontier Research Center renewed in September 2022 by the Department of Energy.

The Center for Understanding & Controlling Accelerated and Gradual Evolution of Materials for Energy (UNCAGE-ME) is led by Georgia Tech and includes teams from Lehigh, Oak Ridge National Laboratory, Sandia National Laboratories, the University of Alabama, the University of Wisconsin, Penn State University, and Washington University in St. Louis. Since the center's inception in 2014 and through its renewal in 2018, Lehigh has partnered with UNCAGE-ME to help advance our understanding of how acid gases interact with energy-related materials.

In this next four-year, $13.2 million phase, UNCAGE-ME will build upon earlier findings to address basic science questions associated with the evolution of materials to be used in clean energy technologies, including systems designed to capture and convert CO_2 from the air into useful chemicals.

"We will be focusing on mitigating the factors that degrade the performance of hydrogen generation and carbon capture/sequestration technologies," says Israel Wachs, Lehigh's G. Whitney Snyder Professor of Chemical and Biomolecular Engineering (ChBE) and director of its *Operando* Molecular Spectroscopy and Catalysis Research Lab. "To date, most research in this field has examined the inner workings of hydrogen generation and carbon capture/sequestration technologies in lab-controlled environments. With our UNCAGE-ME partners, we're going to address how these technologies work in the real world, where conditions can fluctuate and impurities abound."

The team includes ChBE faculty Jonas Baltrusaitis and Srinivas Rangarajan; graduate students Emmanuel Aransiola, Johari Dramiga, and Neelesh Kumar; and postdocs Bar Mosevitzky Lis and Sahanaz Parvin. The group will study electrochemical conversion of H_2O to H_2 and CO_2 hydrogenation into hydrocarbon fuels and chemicals, as well as high-temperature solid oxide electrolysis for H_2 and hydrocarbon generation.

INTERVIEW BY KATIE KACKENMEISTER

ROLE REVERSAL

A pioneer in the use of microdevices in neuroscience, Professor Svetlana Tatic-Lucic gains an insider's perspective serving as a program director for the NSF

In 2021, Svetlana Tatic-Lucic, a professor of bioengineering and electrical and computer engineering and former Rossin College associate dean of faculty development, temporarily relocated from the storied halls of Packard Lab to the National Science Foundation's 19-story headquarters in Alexandria, Virginia. Tatic-Lucic is on leave from Lehigh lending her expertise in micro-electro-mechanical systems (MEMS) in cell biology and neuroscience applications to the federal agency as a rotating program director within the Division of Electrical, Communications and Cyber Systems. She belongs to the Communications, Circuits and Sensing Systems program cluster and manages the interdisciplinary science and engineering research thrust in the area of sensing and biomedical applications of advanced technologies. From her post, Tactic-Lucic has a front-row seat to the ideas, innovations, and fundamental research that will support the next generation of biological sensing systems and neurotechnologies—advances that could revolutionize medicine and healthcare, environmental and biological monitoring, and related fields. "My entire career has prepared me for this role," she says, "and I feel that I am a very good match for it."

Q: What are your duties at the NSF?

A: I make recommendations for future awards, manage the portfolio of existing awards, and participate in working groups outlining future solicitations. I also had the privilege of being a lead program officer for the Integrative Strategies for Understanding Neural and Cognitive Systems Program in the past year. It was a challenge and an honor to head this cross-directorate program as a brand-new program director, and I learned a great deal.

Q: How does your research expertise support you in this role?

A: The field of sensors, in general, is very interdisciplinary, because it assumes knowledge and understanding of various branches of engineering, physics, and chemistry. And in my specific field of interest, biology is needed as well. This breadth gives it charm and irresistible allure, at least as far as I am concerned.

I've worked in interdisciplinary research since my first job, and my PhD thesis focused on applications of microdevices in neuroscience. I still remember that my fellow students were amused that I had to be cross-trained in biology. Back in the early 1990s, sessions on sensor applications in biology were poorly attended at major conferences. Many people moved to this field later because of more abundant funding, but I was there from the very beginning of my career.

Q: How do NSF program officers affect the direction and trajectory of STEM research?

A: Feedback from the review panel plays the biggest role in any funding decision. However, each program director submits a recommendation, based on their insight into the field and what they see as the most promising venues of research, that is considered as part of the evaluation process.

Even more important, we have an opportunity to initiate and shape new solicitations and Dear Colleague Letters, which are special requests for research proposals, often tied to societal needs or unique circumstances like the pandemic. This process was a black box for me prior to joining the NSF, and it has been interesting to peek behind the curtains and get to know the intricacies of the process.

Q: Why is it beneficial for researchers to serve a rotation as a program director?

A: From my first visit to the NSF, which was early in my academic career, I wished to one day work there and make a contribution. I believe it is beneficial for both researchers and their home institutions. This position gives you a big-picture view of where STEM research is going and insight into how you can contribute in your specific field, particularly as it applies to the NSF's grand challenges. You gain an insider's perspective into how proposals are processed and learn strategies to maximize the chances of securing NSF funding. When program directors return to their home institutions, they can pass that knowledge along by mentoring other faculty.

COURTESY OF NSF

Q: Why did you choose this new path?

A: I see this job as a way to round out a full deck of experiences in my career as an engineer and scientist. I've worked for an industry giant and a startup. I've made my way up the ranks as a professor and served as an administrator. Now I'm working in the government. I think it is a royal flush of career experiences, and I am proud of my achievements. Not bad for a girl from a small town in a war-ravaged country in Southeastern Europe.

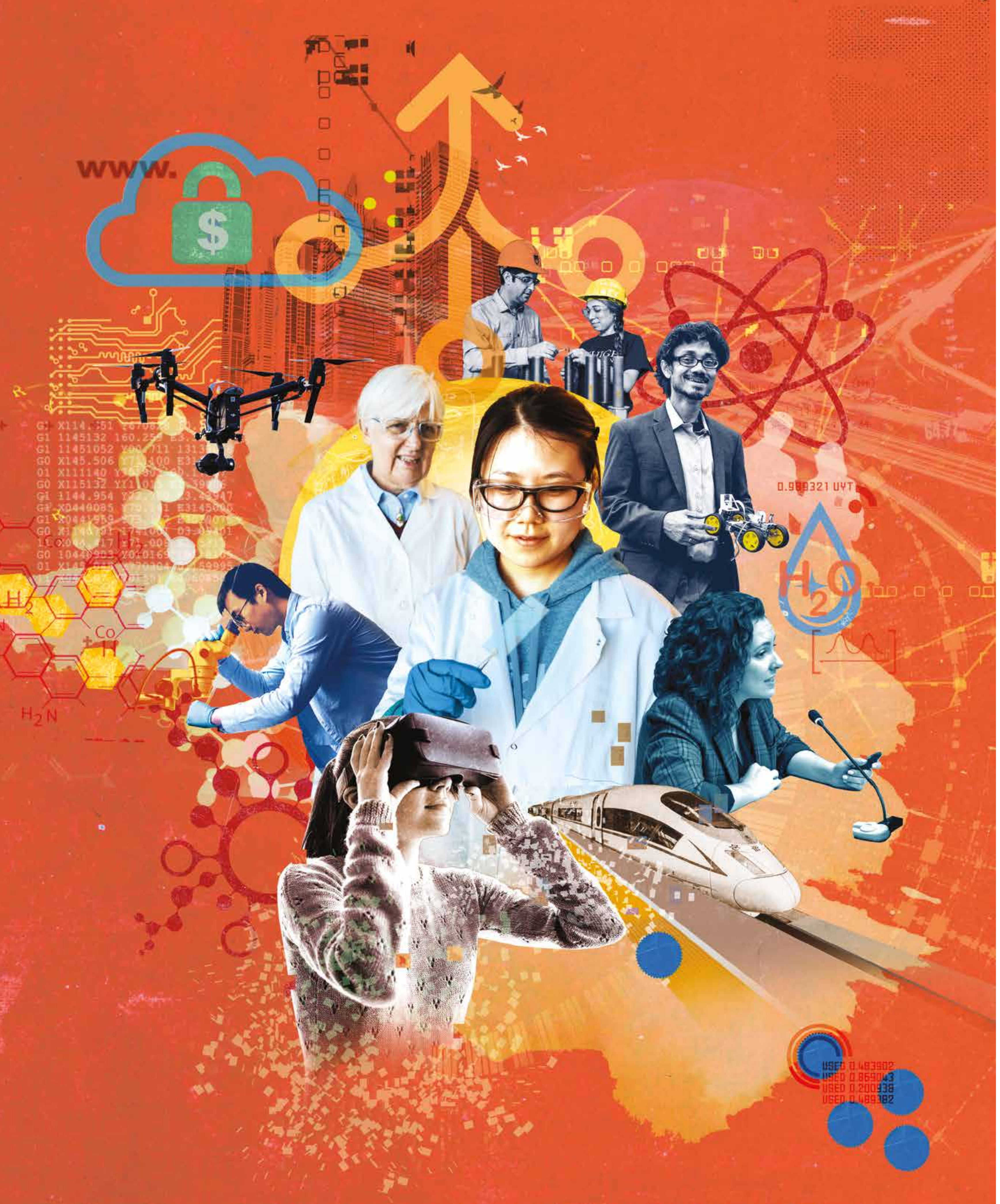
Q: What have you learned about the proposal process, and specifically about the NSF's focus on convergence research, from sitting at the other side of the table?

A: It is very important that researchers are well-prepared and have an awareness of the opportunities and a wide-ranging network of possible collaborators. Communicating with the potential program director up front, to be sure that proposals are submitted to the right place, is critical. Convergence research is extremely impactful, but conducting research across different disciplines of science and engineering is far from easy. Flexibility is essential.

> "Convergence research is extremely impactful, but conducting research across different STEM disciplines is far from easy. Flexibility is essential."

Q: You have been deeply involved in the Rossin College's efforts to improve diversity, equity, and inclusion within the academic environment. How can similar goals be supported by funding agencies?

A: The NSF is very focused on making strides in these areas, specifically in regards to broadening participation in STEM. We are attempting to develop and implement innovative strategies to increase the participation of people from backgrounds that are underrepresented in our fields. Other funding agencies have similar efforts, and in concert with what is going on in academia, I hope we will see some tangible results soon.



MEETING OF THE MINDS

STORY BY CHRISTINE FENNESSY | ILLUSTRATIONS BY SARAH HANSON

Lehigh's diverse expertise and culture of collaboration provide fertile ground for convergence research—with two unique cross-college projects taking root out of the COVID-19 pandemic

We live in a world that demands creative problem-solving. And such creativity is inevitably sparked when disciplines come together to look holistically at a problem.

"Humans are facing challenges that are multifaceted and complex, and require an interdisciplinary approach for their solution," says Anand Jagota, a professor of bioengineering and chemical and biomolecular engineering and Lehigh's vice provost for research. "While incredibly important work continues within the confines of each discipline, innovation is occurring at the interfaces between them."

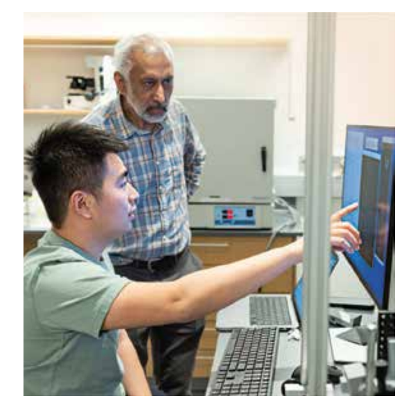
That is the essence of convergence research, or what the National Science Foundation defines as work driven by a specific problem or societal need that brings together an intellectually diverse group of experts (in some cases, drawing from areas beyond traditional STEM fields). In recent years, the NSF has increasingly emphasized this approach—and supported it through an array of grants and workshops—as a way to frame research questions in new ways and spur discovery.

Boundary-crossing team science has long been part of the Lehigh research ethos. For example, The Humanities Lab weaves the study of history, language, society, and related fields into scientific pursuits. The Nano-Human Interfaces Presidential Initiative, which connects engineers with experts in human cognition, psychology, and education, seeks to redefine the interaction between scientists and their instruments. And the university's three Interdisciplinary Research Institutes are developing research strengths across Lehigh's colleges to address large-scale societal problems around materials and devices, data and computation, and infrastructure and energy.

All of these efforts use an interdisciplinary approach to advance knowledge and discovery. Creating and fostering that kind of collaboration is a function of both place and people, says Jagota.

"A medium-sized institution like Lehigh really promotes interactions between researchers," says Jagota. "But our real strength is our culture of collaboration. We want to work together, and we're always looking for ways to do that, and do it better. At the end of the day, the goal is to make an impact with the work we do. And our chances of doing that are always greater when we approach it as a team."

The NSF has supported a number of Lehigh's interdisciplinary proposals that combine the university's research strengths in new ways. Two of the most recent—both rooted in challenges borne out of the COVID-19 pandemic—reflect the depth of problems our researchers are joining together to solve, and the potential they have for creating a healthier, safer world.



Jagota (far left, standing) is part of Lehigh's Nano-Human Interfaces Presidential Initiative, which has a Visualization and Data Analysis Lab (left) in the HST Building.

DOUGLAS BENEDICT/ACADEMIC IMAGE (2)

Studying pandemic dynamics in Indigenous communities

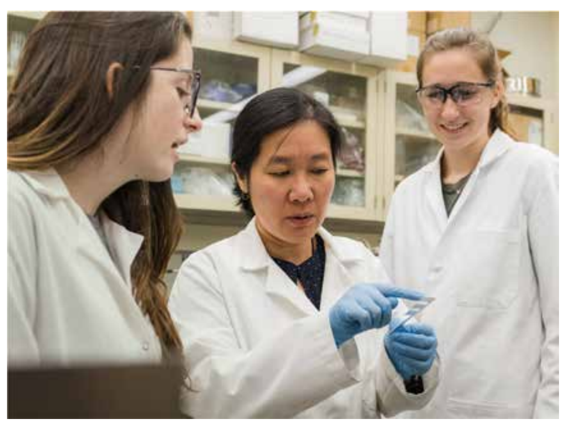
Imagine if researchers could predict the spread of a pandemic like they can the evolution of a hurricane. With the right data, they could help people stay out of harm’s way.

Harnessing that ability is the bold vision of a Lehigh team recently awarded a $1 million grant to examine pandemic dynamics within isolated and underserved populations. The funding comes through the NSF’s new Predictive Intelligence for Pandemic Prevention (PIPP) program, which promotes convergent research by diverse, multidisciplinary teams spanning engineering, computer science, biology, and the social sciences.

“When the call for proposals came out, we recognized that Lehigh had expertise in all of these areas,” says Jagota, the project’s lead researcher. “But these faculty members had not yet worked together around a common theme.”

To be competitive, they needed to identify what set them apart from other applicants. The answer soon became clear.

“What really distinguishes Lehigh as an institution is the Institute for Indigenous Studies (IIS) within our new College of Health,” says Jagota. “The institute gives us access to communities that, historically, have suffered disproportionately compared to the general population in every pandemic in modern history. Having this connection gave us a unique angle to look at the problem of pandemic prediction and prevention.”



Falk (above) will study how viruses are transmitted from cell to cell. Cheng (right, center) will develop point-of-care diagnostic devices.

CHRISTA NEU (2)

The IIS partners and collaborates with Indigenous peoples, nations, communities, and organizations to improve their well-being. Under the auspices of their proposal, Jagota’s team—which includes 13 faculty members, two industry collaborators, the healthcare provider Geisinger (which will serve as both a research collaborator and clinical partner), and members of two tribes—will examine how disease, in this case influenza, affects underserved and isolated Indigenous communities in various parts of the country.

It’s a singular opportunity, says College of Health professor Christine Makosky Daley, chair of the Department of Community and Population Health and cofounder of the IIS. Daley is an applied medical anthropologist who says she has been working with American Indian communities since 1995 on topics such as tobacco cessation.

“I’ve spent my entire career trying to convince researchers to please, please, please come work with these communities—they need what you can deliver,” says Daley. “And I’ve been met with responses like, ‘They’re only three percent of the population, or it’s too hard to get to where they live.’ That’s very frustrating as you’re trying to respond to community needs. And for the first time, really ever, when I got to Lehigh, I met researchers who said, ‘Yes, I want to do that.’”

She credits that willingness, in part, to Lehigh researchers feeling comfortable with the unknown. Whereas in traditional research, investigators are continually building on what they know, committing to a project like this, she says, requires learning a new culture and working with colleagues who do things very differently.

“Working with a new community is a big step,” she says. “And it’s one that a lot of people aren’t willing to take because they see it as setting them back. You have to relearn things from a new perspective. But I think people at Lehigh are willing to take a chance like this because they can see the bigger picture.”

The team’s innovative collaboration cuts across the fields of engineering, biology, data science, and cognitive psychology, and their approach is organized around four research thrusts.

The first will be led by Jessecae Marsh, an associate professor of psychology in Lehigh’s College of Arts and Sciences (CAS), and will establish the belief system around disease within Indigenous communities.

“So, how do these beliefs develop?” says Jagota. “How do they affect the progression of disease? How do they affect whether people get vaccinated?”

The second thrust will model virus spillover and spread, and will be headed by Paolo Bocchini, a professor of civil and environmental engineering.

“We’ll be using our Catastrophe Modeling Framework,” says Bocchini. “It’s a modeling approach that started with natural disasters, but we’re trying to push well beyond that now. In fact, we’ve been applying it to diseases like Ebola. [See page 3.] With the PIPP grant, we’ll work on modeling spillover from animals to humans, and start laying the groundwork for probabilistic models detailing spread among the human population.”

Lehigh’s strengths in data analysis “will play a particularly key role when it comes to studying American Indians,” says Daley. “When you have these very small populations, you need gigantic data sets to find these folks, and you need to use sophisticated statistical techniques that you usually have to develop yourself. And we have people here who can do all that.”

Xuanhong Cheng, a professor of bioengineering and materials science and engineering, will lead the third thrust, which will focus on developing point-of-care diagnostic devices, as many of these communities are often located far from testing centers.

The idea that her team member can simply make a device has been another rather mind-blowing revelation for Daley.

“I have always been the person who is looking for these devices,” she says. “But having engineers around telling me, ‘Oh, we can just make that,’ has been pretty cool.”

The fourth thrust has two aspects, says Jagota, and will seek to determine if researchers can detect the biological basis of why some people get sick and some people don’t and whether a person’s genetics or environment “is the main culprit.”

Biological sciences professor Matthias Falk (CAS) will examine how viruses are transmitted from cell to cell, and how that might lead to variability in the response to infection. Jagota will look specifically at the role of the glycocalyx, the protective layer that surrounds the cell.

“We hypothesize that this glycocalyx is very important in determining whether the virus sticks to the cell or not,” he says. “The cell membrane has a bunch of hairy molecules on its surface, which the virus has to get through, and so far, researchers have sort of ignored that fact. We’re pursuing the hypothesis that the variability with which the virus sticks may have to do with the variability of the glycocalyx, and that may have to do with your environment or with genetics.”

To that end, he’ll develop an assay to directly measure how strongly a viral particle sticks to a cell surface as the nature of its glycocalyx is manipulated.

“First, we just want to see if we can do this with cells in a model system,” he says. “If we’re funded for Phase II, we’ll use human samples.”

The team’s PIPP Phase I development grant gives them 18 months to gather preliminary data to show proof of concept—that the combination of these approaches could yield successful prediction models in these areas.

> “Working with a new community is a big step. And it’s one a lot of people aren’t willing to take. But people at Lehigh are willing to take a chance like this because they can see the bigger picture.”
>
> —Christine Makosky Daley

The ultimate goal is to secure funding in Phase II for the establishment of a formal research center.

“The idea is to create a center in which we’re able to use computational modeling, engineering, biology, and social science to predict pandemic spillover and spread in underserved and isolated communities,” says Bocchini. “The hope is that what we learn will have relevance at the national scale, because protecting these communities is a way to protect all of society.”

There’s an additional element to this project unrelated to pandemic prevention, but very much in keeping with the NSF’s push toward promoting convergent science. Throughout the Phase I data-gathering period, a team led by psychology professor Kate Arrington will study the group itself—specifically, its dynamics and effectiveness in conducting team science. To facilitate this line of inquiry, all meetings will be recorded and representatives from each thrust area must attend each meeting. Arrington will examine team member interactions, publications, and progress.

“We decided that because our group is so large, it would be a great opportunity to study how well we do team science,” says Bocchini. “How we interact, how effectively we communicate, how easily we adjust our scientific protocols to make them compatible with someone else’s.

I think the most interesting research projects really happen at the intersection of various disciplines, so I find the idea of studying how we work together fascinating."

There's a tremendous amount of work to be done for the team to make it to the next step. But Jagota is optimistic. Their group is a formidable one, united by the potential for impact of a center devoted to pandemic prediction and prevention in Indigenous communities—and ultimately society at large.

"One of our researchers, Thomas McAndrew [an assistant professor in the College of Health] says it best," says Jagota. "We'd like to be able to contribute through surveillance, through measurement, through psychological work to predict the progression of a pandemic. Just the way people can predict the weather right now."

Examining social media's role in framing facts, influencing behavior

The onset of the COVID-19 pandemic coincided with an era in which people the world over have the technology to document and share their experiences with and perceptions around the virus.

"I was really moved by the personal storytelling I saw on social media," says CAS faculty member Haiyan Jia, an assistant professor of journalism and communication. "At the same time, I saw how those experiences were reflecting very different realities."

"You can't necessarily tell people how they should think. You can make conscious, intentional choices about the resources you make available to people to support their understanding of this dynamic, evolving crisis."

—Eric P. S. Baumer

The more she read, the clearer it became that such personal accounts were very much influenced by the information people were consuming.

"As a media researcher, I was fascinated by this," she says. "I'm always trying to better understand how technology shapes our cognition, emotions, and behaviors, and this was a unique moment playing out in real time."

That fascination has led to a nearly $1.2 million NSF grant that is funding an interdisciplinary team investigating the role of online media in framing processes—essentially, how individuals and communities develop their understanding of major events and, ultimately, act on that understanding.

In addition to Jia, the team includes two computer science and engineering faculty members—associate professor and lead researcher Eric P. S. Baumer and assistant professor Dominic DiFranzo. Also on the team is Amanda Greene, a former postdoctoral research associate in The Humanities Lab, who is now with the Center for Bioethics and Social Sciences in Medicine at University of Michigan Medical School.

The grant stems from the National Science Foundation's Information and Intelligent Systems division, which supports research that probes the intersection of people, computers, and information.

The kernel for the idea came from initial conversations between Jia and Baumer in the spring of 2020, and Jia's realization that English-language, U.S.-based coverage of the pandemic reflected a very different reality when compared with coverage coming out of China.

"There are fundamentally different ways of organizing basic facts," says Baumer. "Taking the same exact facts and organizing them in a different way leads to different conclusions about: Should we be wearing masks? Should we require vaccines? Should children be in school or be vaccinated? How we organize and give meaning to the events in the world draws on this theory called framing. And how we frame these events ultimately leads to what actions we take in the face of them."

What's interesting, says Jia, is that social media has upended who gets to do the framing. Yes, the main purveyors of information—particularly around COVID—are public health departments, government entities, and the news media. But individuals and online communities are doing their own framing—piecing together what most resonates with them, creating their own narratives, and ultimately influencing people's reactions to and behaviors around the pandemic.

"What's also unique here, is that while we often talk about news frames as fixed moments in time, the pandemic has been going on for years, which means the narrative around it has been changing," she says. "For example, take a person who may not have initially believed that COVID was a threat. If they lost someone in their family to the virus, that event might have changed their view completely, and they might be motivated to get vaccinated or be more willing to wear a mask. So we wanted to start thinking about framing as a process, and identify those things that trigger changes in people's understanding or framing of COVID over time."

It's not a purely academic exercise, says Baumer. The implications of their research could better inform public health communicators responding to crises.

"You can't necessarily tell people how they should think," he says. "But you can control the kinds of resources that you give them for interpretation. The choices of language, the specific metaphors that are invoked, stereotypes, imagery. You can make conscious, intentional choices about the resources you make available to people to support their understanding of this dynamic, evolving crisis."

To that end, the project will unfold in four phases, each reflecting the team's interdisciplinarity. The first phase will be led by Jia and Greene and use qualitative methods from media studies, health humanities, and science and technology studies to better understand how groups like community organizations, local leaders, and online communities describe their framing process. It will also involve content analysis of the groups' social media, as well as information published by news organizations and governmental and health agencies.

Baumer, who studies human interactions with algorithmic systems, will lead phase two, which will involve computational analysis of much of that same content.

"We want to build models that help us understand how these framing processes play out in the kinds of language patterns that tend to co-occur with certain metaphors or visual imagery," he says. "So the first and second phases will be in dialogue with each other, with each informing the other. That will allow us to see what's going on, and the way that people are talking, but it doesn't necessarily tell us anything about causal connections. That's what the third phase is for."

That third phase will be led by DiFranzo, who will take the results of both the qualitative and computational analyses and formulate testable hypotheses. DiFranzo's research focuses on human-computer interactions and "design interventions" that encourage pro-social behavior online. He also develops novel tools, platforms, and methods to help researchers study social media. (See page 4.)

"The idea is to develop web browser plugins where you can make subtle manipulations in the content that people see, for instance, on Facebook, on Twitter, on Instagram, or on Reddit, to test these hypotheses," says Baumer. "If we change what people are seeing, does that change their perceptions? Their opinions? Their subsequent behaviors?"

The fourth phase will involve a process called reflexive engagement. Findings from the previous phases will be brought back to those groups who were initially interviewed, with the idea that they might draw on those results in a future health crisis, says Jia.

Jia (left) and DiFranzo (above) are part of a multidisciplinary, cross-college team investigating how online media affects our understanding of major events and our reactions to them.

LEFT: JASON WANG; RIGHT: RYAN HULVAT/MERIS

"This is about making a real-world impact," she says. "We want to go back to these groups and say, 'Here's what we found, this is what we know about the facts of framing, what do you think?' The idea is that they might then be able to look back at their communication strategies from 2020, and identify where they could have done better."

It's a project that could only be accomplished with the unique blend of expertise within the group, says Baumer.

"Because we each came at this from different disciplines, we each had a slightly different perspective," he says. "And that's allowed us to get to this point where we have a potentially novel way of thinking about and examining framing. Personally, I'm excited about the innovative computational methods that we're proposing. I've done prior work collaborating with social scientists and humanists who are interested in using computational techniques, and so I'm really looking forward to expanding on that with this team."

Such innovation and potential for impact could never happen without researchers being willing to step outside the comfort zone of their chosen discipline. Again and again, Lehigh researchers are taking risks and engaging in fields far outside their own to push the boundaries of creative problem-solving. Yes, it's a mindset that is rewarded by the NSF, but it's also a mindset with its own rewards.

"This team approach to research gives us the opportunity to solve knotty problems, the kind that previously you might never have considered tackling," says Jagota. "And in the process, you inevitably find new fields of inquiry and make new discoveries. And so it becomes self-fulfilling, and something that, I think, will become the gold standard for how lasting impact is made."

ENVIRONMENTAL INTELLIGENCE

STORY BY CHRISTINE FENNESSY
PHOTOGRAPHY BY CHRISTA NEU

Civil and environmental engineers are on the front lines of efforts to adapt to a changing climate, where natural disasters are more frequent and natural resources increasingly scarce. Meet three new Rossin College faculty members who are taking innovative, data-driven approaches to sustainability challenges involving water, energy, and infrastructure—and their impact on people and communities.

LEFT: ISTOCK/BILLNOLL; ISTOCK/CREATIVE-TOUCH; ISTOCK/TOMOGRAF

FARRAH MOAZENI

SECURING MODERN WATER SYSTEMS AGAINST CYBERATTACKS

"Everyone should have equal access to water and to energy," says Farrah Moazeni, an assistant professor of civil and environmental engineering. "Equity is the ideal, and so that's our goal."

Moazeni researches modern water infrastructure systems and how to make them more efficient and resilient. Water distribution systems comprise a vast, dispersed network that includes a water source like a reservoir or well, pumping stations that pressurize the water and allow it to travel long distances, and miles and miles of piping with countless valves that direct the flow to your faucet. In contrast to older systems that relied on telemetry, smart infrastructure is equipped with Internet-of-Things devices that gather data at various points throughout the system.

"And we can use the data to make sure the assets in the infrastructure are optimized and working at their best," says Moazeni.

She and her lab also use the data to help secure the system against cyber attacks. Specifically, her team is focused on stealthy false-data injection strikes, where attackers are able to bypass detection algorithms and cause cascading failures across the water system. Moazeni says the goal is to identify vulnerable areas and, using artificial intelligence and machine learning, develop models that will thwart such interference.

"We're also working to make sure that even if an attack happens, it's mitigated in the shortest amount of time possible so that people don't go without water for too long," she says.

Data generated by these modern water systems can also be used to communicate with other systems. What people don't often realize, says Moazeni, is that using water requires energy. It takes a lot of power to run treatment facilities and transport water—so the more water you use, the more energy you consume. Communication potentially can be leveraged to make both systems more efficient.

"So another part of my work is the controlling of interconnected water and energy systems," she says. "There are a lot of us involved in this research project because each of these systems on its own is so complex—highly nonlinear and highly uncertain. Now imagine trying to control and optimize them simultaneously while meeting both water and energy demand. It's very challenging."

To meet that challenge, Moazeni is working with colleagues across civil and environmental engineering and electrical engineering to develop a framework called model predictive control that will help them coordinate the two systems.

The ultimate goal, she says, is to establish an urban system where water, energy, transportation, and building systems are all connected and optimized so that consumption, emissions, and costs all go down while access for all goes up.

"Imagine if you could do that for the entire United States," she says. "You would have all these interconnected systems lending and borrowing from each other, depending on the need at any given moment, so that no matter where you live, you have uninterrupted, reliable, and resilient access to these resources."

Moazeni talks about working toward equitable access to resources, and leaving her life in Iran, on the Rossin Connection Podcast.

MARYAM RAHNEMOONFAR

A CLEARER VISION FOR RESILIENT COMMUNITIES

It can be difficult—and dangerous—for response teams to assess the aftermath of a major disaster with conventional techniques. Ground-based robots are one alternative to collecting information on the damage, but they, too, can be hindered in speed and scope by a storm's detritus. So first responders are increasingly relying on aerial and satellite imagery to reveal the situation on the ground.

"But this kind of imagery comes with its own challenges," says Maryam Rahnemoonfar, an associate professor with a dual appointment in computer science and engineering and civil and environmental engineering. "When you take an image with a handheld camera from the ground, you can see all the objects and their features, like the doors and windows of a house. But with overhead imagery, one can only see the roof of the house, features are tiny, and there's no balance between foreground and background. So it's very difficult to decide if the house is totally destroyed, or if what you're seeing is actually part of the road next to the house."

Rahnemoonfar uses a combination of computer vision (i.e., simulating with computers how the human eye and brain interpret the visual world), machine learning, and remote sensing to develop better tools to analyze aerial imagery. Her cross-departmental appointment will allow her computer science students to work on a real-world problem, using advanced techniques not traditionally applied in civil engineering.

"The idea is to train the next generation of students in a domain that bridges these two disciplines," she says.

Rahnemoonfar has long worked at the intersection of the two fields. For the past decade, she was leading a project using radar imaging to monitor changes in Arctic and Antarctic sea ice. The technique uses radio wavelengths to send out pulses of light and measures the strength and time with which those signals are reflected off an object to create three-dimensional images.

"Radar is the only sensor that can penetrate the ice and the soil to give us information below the surface," she says. "The problem was that there were no advanced data analytics techniques to process all of that data. Our group was the first of its kind to develop the models to make sense of all of this data collected over the years. Ultimately, it will lead to a better understanding of the factors that affect sea-level rise."

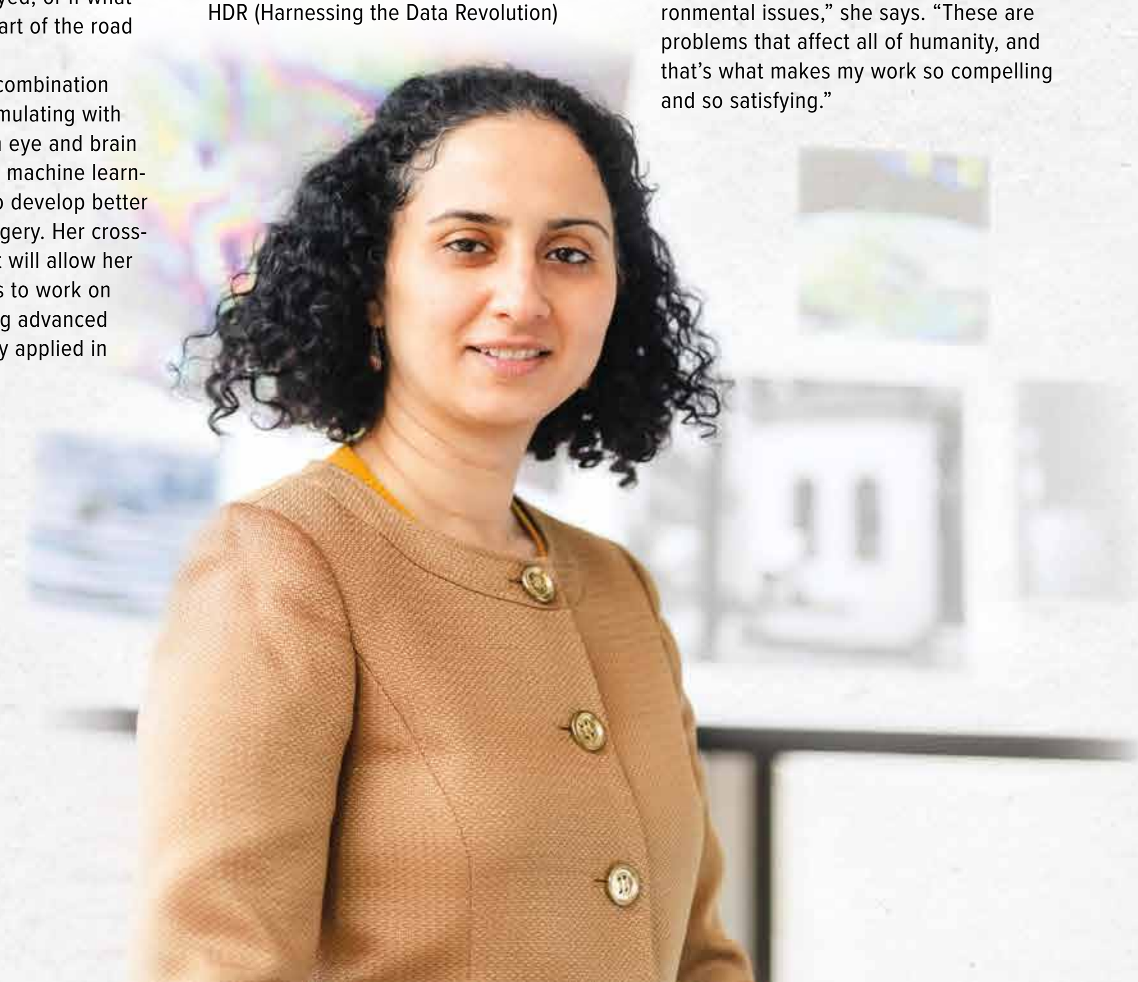
> "SOLVING PROBLEMS THAT AFFECT **ALL OF HUMANITY** MAKES MY WORK **COMPELLING** AND **SATISFYING**."
>
> —Maryam Rahnemoonfar

She previously led a multi-institution, multidisciplinary team that established an inaugural National Science Foundation HDR (Harnessing the Data Revolution) Institute for Data-Intensive Research in Science and Engineering. The institute studies polar regions and their contribution to sea-level rise using a combination of machine learning and physical models.

At Lehigh, Rahnemoonfar is leading a project to develop physics-informed machine learning algorithms for polar ice dynamics for the NSF-funded Leadership-Class Computing Facility in collaboration with the Texas Advanced Computing Center at the University of Texas at Austin. She'll be employing similar techniques alongside colleagues who are developing models to better predict situations like flooding after a hurricane. If experts can better predict such events, she says, they can better prepare communities or help them evacuate.

Her cross-disciplinary appointment is a natural fit for her strengths as a researcher, and her skills as an educator. It's also directly in line with her passion.

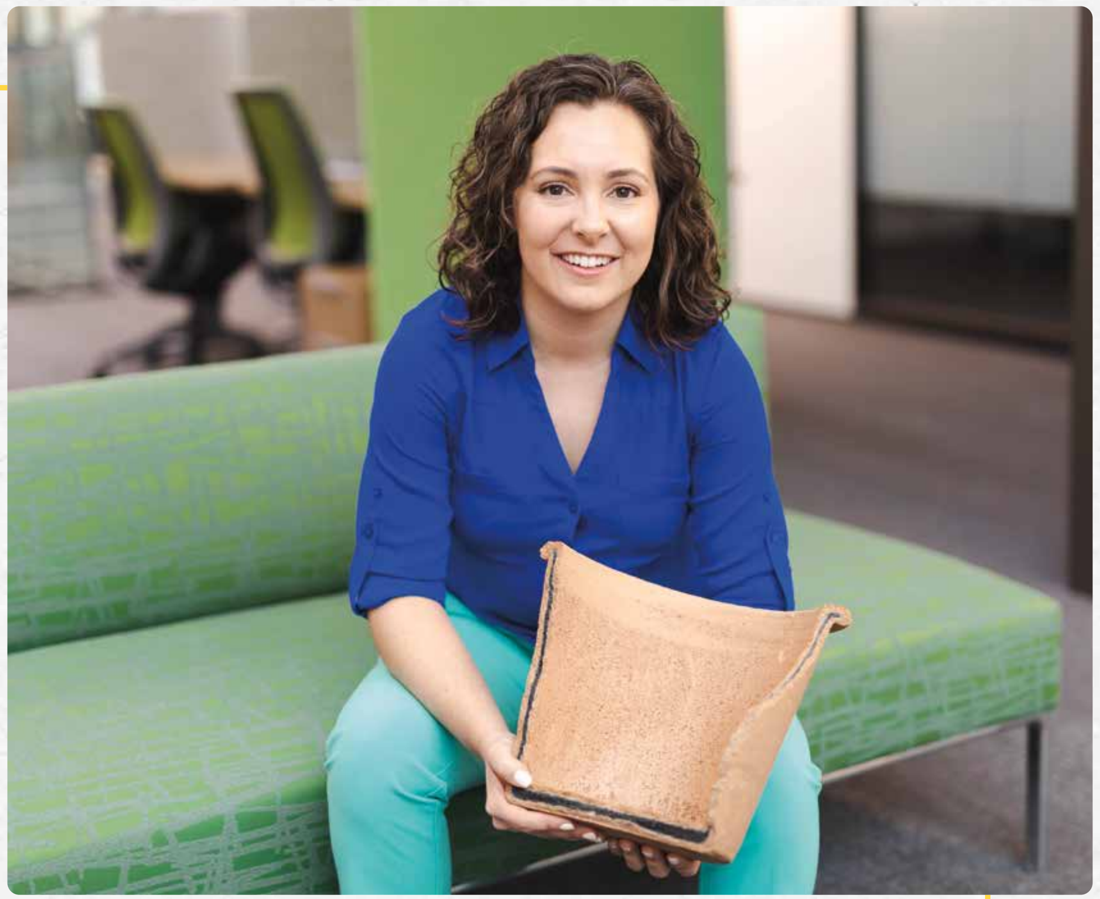
"I have always been interested in developing computer science and data-science techniques capable of solving real-world problems, particularly environmental issues," she says. "These are problems that affect all of humanity, and that's what makes my work so compelling and so satisfying."



Rahnemoonfar is using her unique expertise and her dual appointment to train students in a domain that spans computer science and engineering and civil and environmental engineering.

GABRIELLE STRING

ENVIRONMENTAL HEALTH ENGINEERING FOR EFFECTIVE CRISIS RESPONSE



Once people get involved, even the best engineering solutions can come undone.

"You could have the most technologically advanced filter system for treating drinking water sitting in someone's kitchen, and they might never use it," says assistant professor Gabrielle String. "Maybe it's too expensive or complex to operate, or replacement parts are too difficult to find. Or maybe someone doesn't trust the unit or the people implementing it, or like the taste of the treated water. Just because something works technically doesn't mean it's appropriate for—or will translate to—effective implementation in other contexts."

String, who has a dual appointment in civil and environmental engineering and Lehigh's College of Health, will help students learn to navigate scenarios where success of an implementation is often driven by external context and people, and not the limits of technology. In other words, she says, getting them comfortable with the gray areas.

"My work is not black or white, and the answers can often be very frustrating. But when someone says, 'I'm not going to put chlorine in my water because I believe it's a form of birth control,' that information is critical to gauging the effectiveness of a water treatment program and to understanding the perceptions and beliefs of a community."

As an environmental health engineer specializing in water sanitation and hygiene, String has worked in humanitarian response and development in countries like Haiti, Democratic Republic of the Congo, Nigeria, Bangladesh, and Mozambique. In the lab, she tests the efficacy of related protocols and technologies, and in the field, she evaluates their real-world implementation.

"What happens when you take these things out of the perfectly controlled lab environment? Some of these sanitation and hygiene programs—like treating cholera bacteria in water with chlorine—have been implemented for decades, but there's actually a lack of evidence around many of the program guidelines," she says. "So we investigate them, and help organizations draft recommendations to improve the response they're getting to their interventions."

Such investigation requires mixed methods research. The approach involves data collection (including interviews, surveys, observation, and lab analysis) that's both quantitative and qualitative. Data points can show that water quality is improving, she says, but interviews with people can reveal whether results will continue. Mixed methods give a more holistic picture of a program and its effectiveness. By training her students in the approach, she'll equip them with the skills necessary to navigate the ambiguities inherent when working with technology and people.

At Lehigh, String will continue her work supporting rural community-managed water-safety plans in the South Pacific, and looking at gloving protocols for healthcare workers in Ebola treatment units. She also hopes to restart a project evaluating safe water storage in jerricans (sturdy, narrow, flat-sided fluid containers) that was derailed by the pandemic. She is certain, however, that her position at the intersection of the university's engineering and health colleges best speaks to her research—and the potential she has to impact students and expand their career aspirations.

"This is important research," she says. "People deserve to receive programs that are evidence based and that are going to work. And if the work we do can provide that evidence, we can take one burden off the plate of responders during a humanitarian crisis. Because their mandate is saving lives."

Above: String holds a ceramic-pot water filter made in Guatemala for household treatment of drinking water. Inset: A simple water-testing kit used in the field.

TOOLS OF THE TRADE

Lehigh's research infrastructure gets a boost through two National Science Foundation grants for instrumentation development and upgrades

— BY **CHRISTINE FENNESSY** —

Optical tweezers. A deep silicon etch tool. A small angle X-ray diffractometer.

It's a wish list of sorts. But not the type you can fulfill on Amazon.

"To pursue groundbreaking science and engineering research requires sophisticated instrumentation," says John P. Coulter, a professor of mechanical engineering and mechanics (MEM) and the Rossin College's senior associate dean for research. "The NSF's Major Research Instrumentation program provides critical support for universities to invest in these tools and facilities that will shape research and help train up-and-coming researchers."

To date, Lehigh has received more than 20 MRI grants (which can range from $100,000 to $4 million). The two most recent are led by Rossin College faculty and bring in a total of nearly $2.3 million for equipment to be housed in the Health, Science and Technology (HST) Building.

"Overall, receiving these grants signifies there's a compelling need for the instrumentation, and that the university has the related expertise and human capital to use it to tackle grand challenges and gain new knowledge that can make an impact on society in the long run," says Coulter. "This latest investment continues to strengthen Lehigh's internationally recognized capabilities in materials research and microscopy."

Uncovering 'weak links' in microstructures

Thanks to a nearly $1.3 million MRI grant awarded in 2022, researchers across Lehigh will soon be able to conduct experiments using a state-of-the-art plasma focused ion beam system, or FIB, together with the capability for *in situ* mechanical testing at various temperatures between minus 130 and 1000 degrees Celsius.

"We had 25 faculty members involved in this proposal, all of whom submitted projects requiring the FIB system, and many of them are associated with Lehigh's Interdisciplinary Research Institutes," says Masashi Watanabe, a professor of materials science and engineering and a major contributor on the proposal. "And they represent a range of disciplines. There's just such a high demand for a machine like this."

"The FIB system is a micro-/nano-fabrication tool that is able to precision-machine samples in a rapid, efficient way, similar to woodworking, but at the micrometer or even nanometer level," says lead researcher Helen Chan, New Jersey Zinc Professor of Materials Science and Engineering. "The fixture that allows for mechanical testing in real time enables us to indent or pull or push on a material so we can simultaneously watch how it fractures and deforms. Even more exciting, we can study the effect of temperature on the deformation process."

Chan says the EBSD (electron backscattered diffraction) capability is exciting because when certain materials are subjected to a stress, a phase or orientation change can take place, and this is detectable by EBSD. "These changes are often highly localized, and hence difficult to observe in bulk samples," she says. "With *in situ* mechanical testing with EBSD analysis, we can observe these changes as a function of the stress and correlate with changes in the properties."

The new instrumentation also includes an ultra-high-speed electron camera for acquisition of EBSD patterns.

"This capability will allow us to see the orientation, meaning the crystal structure of a particular sample," says Watanabe. "We'll be targeting 2000 to 3000 patterns per second, which is incredibly fast. So during deformation, we'll be able to see these crystal structures change as the change is taking place."

"This is very new," he continues. "No research team on Earth has yet been able to achieve this."

Such information will inform researchers on how cracks in structures initiate, says Chan. There may be "weak links" in the microstructure that could be alleviated by improved processing. "We would like to build 'crack stoppers' that make it more difficult for cracks to propagate throughout a structure," she says. "The net result would be structures that exhibit higher toughness and longer lifetimes."

The Lehigh team behind the effort also includes Coulter and fellow MEM faculty member Natasha Vermaak, as well as Wojciech Z. Misiolek, the Loewy Professor of Materials Science and Engineering.

ISTOCK/DENKCREATIVE; © EUCALYP VIA CANVA.COM

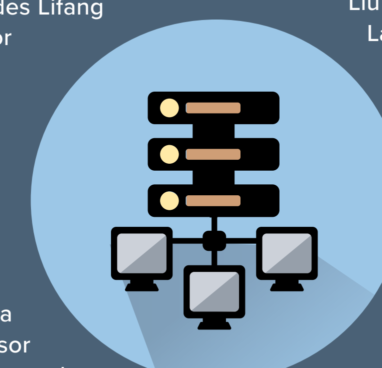
ADOBE STOCK/BESTVECTORSTOCK; PHOTO COURTESY OF UC DAVIS/CC BY 2.0

Getting technology closer to the action

Lehigh's second MRI grant funded in 2022 received nearly $1 million, and it will also allow researchers to try something completely new.

"No one else, to our knowledge, has tried to put such a high-speed computing cluster so close to the equipment in their labs," says Yaling Liu, a professor of bioengineering and mechanical engineering and mechanics. "We believe the facility we're proposing will have a huge impact on our campus by enabling big-data analysis and new science."

Liu leads the Lehigh team that was awarded the MRI grant to fund the development of a "heterogeneous edge computing platform" for real-time scientific machine learning. The team includes Lifang He, an assistant professor of computer science and engineering; Wujie Wen, an assistant professor of electrical and computer engineering; Yue Yu, an associate professor of applied mathematics in Lehigh's College of Arts and Sciences; and Joshua Agar, an assistant professor of mechanical engineering and mechanics at Drexel University.



Heterogeneous computing is a technique in which different processors are applied toward the execution of specific tasks, resulting in gains in performance or efficiency or both. Edge computing refers to the ability to process data as close to the data source as possible. Combining the two will the address several critical computing needs.

"Computer clusters are typically located far from the equipment that generates the data," says Liu. "And that distance affects the speed by which data can be analyzed. So what ends up happening is that you collect all this data, and then you spend days or weeks analyzing it after the fact. And if something went wrong with the experiment, you have to go back and repeat it. This can take hours or days—and it can be unnecessarily expensive."

Data storage poses another problem. Equipment like high-speed microscopes generate huge amounts of information, which means researchers like Liu are forced to keep their experiments short. And because of the lag between collection and analysis, the current system doesn't allow researchers to purge redundant or wasteful data. So valuable storage space is sometimes taken up by useless information.

The facility will help circumvent latency and bandwidth challenges, and its proximity to the data sources will allow for real-time analysis and control of optical, scanning probe, and transmission electron microscopy. Liu says the server will be installed in Lehigh's state-of-the-art HST Building, with high-speed fiber connecting it to various labs.

The platform will allow researchers across the university to make advances in fields like wireless communication, healthcare monitoring, bioinformatics, advanced manufacturing, and multiagent autonomous systems, and it will facilitate interdisciplinary teams pursuing novel research directions.

Liu leads Lehigh's Bio-Nano Interface Lab and is interested in the biomedical applications of the new platform. He and his team currently use the high-speed camera of an optical microscope to sort tumor cells from normal cells. But with each blood sample containing hundreds of millions of cells, the researchers are limited by how fast they can sort the cells and how long their experiments can last. And they're unable to make decisions in the moment about what they're seeing.

"We'll be able to do continuous, real-time analysis that will enable us to finish our tasks in one day, rather than over several months," he says. "That will allow us to advance our research, which is incredibly exciting."

ADDING EXPERTISE IN NANOMATERIALS

Award-winning nanomaterials researcher Ricardo H.R. Castro will succeed Wojciech Z. Misiolek, the Loewy Professor of Materials Science and Engineering, as MSE department chair on April 1.

Castro most recently served as the Chancellor's Leadership Professor of Materials Science and Engineering at the University of California, Davis, leading the

Nanoceramics Thermochemistry Laboratory. His work focuses on the fundamental understanding of nanomaterials and their behavior under processing and service in extreme environments, such as high temperatures, complex chemistries, and radiation.

Castro's research group seeks to understand nanoscale effects in ceramic materials and composites and how to optimally process these materials to control their nanoscale behavior. By using a combination of structural characterization techniques, including microcalorimetry and high-resolution electron microscopy, the Castro group has advanced processing techniques to create samples with unique mechanical properties and tolerance to irradiation-induced defects.

Castro and his team are interested in understanding the stability of nanostructures, which has led to a solid theoretical framework for the design of nanocrystalline ceramics that are well suited for extreme (temperature, chemical, etc.) applications.

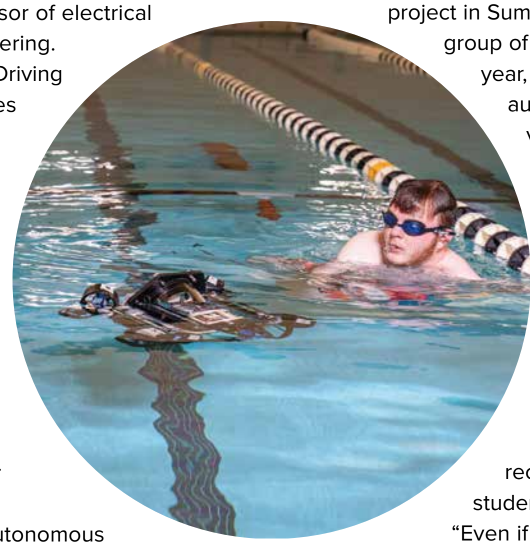
STORY BY CHRISTINE FENNESSY

MAKING A SPLASH

Students dive into opportunities combining hands-on instruction in robotics and autonomous driving with the thrill of competitive racing

It's a uniquely difficult task to build an underwater drone, train its software, and control its movement—all while ensuring the vehicle is fully waterproof and doesn't sink like a brick.

"It is a lot of work," says Yahong Rosa Zheng, a professor of electrical and computer engineering.



The Autonomous Driving for Underwater Drones project is also a creative way to give students hands-on experience with solving complex problems that span a range of engineering disciplines. Zheng leads the project, which is part of Lehigh's Mountaintop Summer Experience. She also teaches a class on Autonomous Driving and Robotic Racing. Both the project and the class are what Zheng calls "student centered."

"Experiential learning puts students in the driver's seat," she says. "They're making things, doing experiments, and taking risks. That means sometimes they fail, but they learn more through trial and error. And then they get to compete with their vehicles. They learn so much by doing, and I think that's what students really enjoy."

Zheng started the Underwater Drones project in Summer 2020 with a small group of undergraduates. Each year, the goal is to build an autonomous underwater vehicle (AUV) capable of accomplishing a series of tasks in a pool. Students can continue working on the project through the academic year as part of a course led by Zheng. The project has also become a recognized Lehigh student club.

"Even if students aren't in the course, they can still join the club and participate in weekly work sessions," she says.

This past summer, the team took their first shot at RoboSub. The international competition (supported in part by the Office of Naval Research) promotes interest in underwater autonomous driving and wireless communication. Participants face simplified versions of real maritime challenges, such as object detection, localization and mapping, robotic arm manipulation, and inter-vehicle coordination. The August 2022 event attracted 39 teams to design, build, and test vehicles to compete virtually or in person at the University of Maryland.

To build their sub, the Lehigh team divided into four groups: The mechanical group designed the vehicle in accordance with the competition's rule book; the electrical team learned to control all eight thrusters and run the battery support system; the software team figured out how to use multiple cameras for image recognition and train the machine-learning engine; and the business team raised the money to pay for it all.

To help guide the team, Zheng purchased a BlueROV2 (the remote-operated vehicle pictured at right) to use as a model.

"They learned how the BlueROV2 worked—what made it waterproof, how the thrusters worked, how the lights turned on and off, how the camera operated," says Zheng. "Then they had to make their own AUV that had to function without the tether. So they designed the entire vehicle, inside and out. The only components that are the same as the BlueROV2 are the thrusters."

The students spent countless hours at—and in—the university's pool observing their vehicle's behavior, capturing image after image to train the machine-learning engine, and making adjustments. They experimented with a depth sensor and a sonar sensor, and they learned concepts like how water flow affected the vehicle and how their 3D-printed parts disrupted buoyancy.

"We learned that lesson the hard way, right before the competition," says Zheng. "There's a buoyancy requirement and these 3D parts had tiny holes that allowed the water to seep in, which made the vehicle a bit heavier after 10 minutes in the water."

They had to overcome other problems, like the fact that pools are full of line markers and reflections that can confuse the software. And while Zheng and other faculty were there to assist, the groups had to collaborate with each other to address issues as they arose.

"By running experiment after experiment, the students were able to learn, make modifications, and improve their vehicle's performance," says Zheng.

And it paid off. At RoboSub, Lehigh took home the Best Rookie Team award.

While exciting, competition isn't the primary focus of the Underwater Drones project. The endeavor is also meant to be a research opportunity.

"We use the vehicle to extract research topics," says Zheng. "For example, there are many solutions to how to control eight thrusters, and so there's a group of students who are working on three different solutions, studying the pros and cons of each."

She says future topics will include underwater communication, direction finding, and SLAM (simultaneous localization and mapping) in an underwater environment.

Zheng offers students a different but related challenge with her Robotic Racing class, in which teams learn how to configure and control AVs that are one-tenth the size of an actual Formula One. The class utilizes the open-source F1TENTH Autonomous Vehicle System, and the vehicles use 2D LiDAR to negotiate a track and avoid obstacles.

LiDAR (shorthand for "light detection and ranging") has been hailed as a game-changer in developing a truly driverless car. Fed into an algorithm, LiDAR data—which is more manageable in size and requires less computation than what's captured by RGB cameras—allows the vehicle to accurately perceive its surroundings and navigate a clear, safe path.

"Students learn to program these autonomous driving algorithms, how to write the code, and how to debug," says Zheng. "They do tests on a simulator to ensure the program is running properly, and then they test it on the vehicle itself."

The hands-on course consists of six projects based on different levels of autonomous driving—like basic reactive algorithms and more advanced SLAM and path-planning algorithms—and three in-class competitions that ultimately serve as the students' exams.

Last year, some members of the class were also on a Lehigh team that won the F1TENTH Virtual Competition Head-to-Head Race. The online event was part of the 10th F1TENTH Autonomous Grand Prix held during the 2022 International Conference on Robotics and Automation in Philadelphia. Two teams from the class also took part in the in-person race.

Students in the Robotic Racing course are graded not only on how well they perform during in-house competitions but also on how they evaluate those performances and how much they participate as a whole, from recording races for their fellow teammates to sharing strategies and lessons learned. It all serves to reinforce the idea that they are the drivers of their own success, says Zheng.

"When they first come to my class, students always ask me, 'What do you want me to do?'" she says. "I always turn that question around and ask them, 'What do you want to learn?'"

For many of those students, it's how to get over the intimidation factor inherent in programming. Some come to the course with little to no prior knowledge of coding, but Zheng has created an environment and a platform that allows them to be curious, ask questions, and take chances.

"And they learn to adapt because this is a field that's constantly evolving," she says. "There are always obstacles as we use the emerging new technologies transferred directly from research to the classroom. But they learn to work together and come up with solutions."

Test-drive Professor Zheng's Intro to Robotics class.

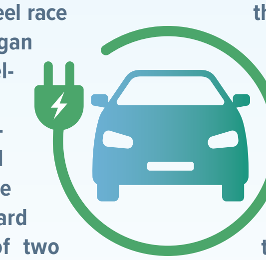
THIS PAGE AND FAR RIGHT: CHRISTA NEU; WATER AT TOP: ISTOCK/PAVLINEC

TOP: BLUE ROBOTICS; BOTTOM: ISTOCK/PANOM73

EVs SPARK NEW EXCITEMENT FOR LEHIGH RACING

The proud legacy of Lehigh's Formula SAE team continues with the upcoming addition of an electric vehicle (EV) to its storied fleet.

Formula SAE is a student-run club open to all undergraduates. Every year, the team designs, manufactures, and competes with an open-wheel race car at the Formula SAE (Society of Automotive Engineers) Michigan competition. This year, team members will also begin the development of an electric motor.

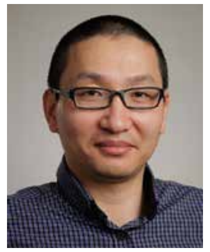


While the goal is to create an EV prototype capable of competition in the spring and summer of 2024, going electric will be challenging. To support the effort, the college will provide students with a multiday safety training specifically geared toward working with high voltage and currents. The curriculum of two courses—one on electrical machines and another on power converters—has been revised to further support the initiative. Advisors, including Bill Maroun (Composites Lab technician), Mark Motsko (IT client support coordinator), and Javad Khazaei (assistant professor of electrical and computer engineering) will work closely with team members throughout the process.

"I have the capacity in my lab to allow these students to test the electrical components before they're assembled in the car," says Khazaei, whose research includes the integration of EVs into the electrical grid. "This is a fairly new research area, and so it's going to be a learning process for all of us. But that's exactly why I'm interested in this project. I think the knowledge we gain by designing this vehicle will apply to my lab's current research efforts."

As for the students, he says, their interest in this emerging technology is undeniable.

"They are super motivated," he says. "If it weren't for the safety requirements, they would have designed the car already. They just want to race tomorrow."



Up to speed

Wujie Wen tackles computing efficiency and security challenges on the cutting edge of artificial intelligence

"My philosophy is, maybe you publish a 100 or so papers in your career, but a few of them should have a direct and immediate impact on the real world," says Wujie Wen.

As an assistant professor in the Department of Electrical and Computer Engineering, Wen puts that philosophy into regular practice. He researches how to improve computing efficiency and security, primarily for machine learning and AI-related applications that will play key roles in the future of autonomous vehicles, healthcare, and other fields. Three of his most recent projects have all been supported by the NSF.

The first addresses the intense energy demands of running deep learning algorithms (the kind that power computer vision and language processing technologies). With traditional computer architecture, computation and memory are accomplished separately in hardware accelerators. "But if you look at neurons inside the human brain," says Wen, "they can process and memorize things. Which is why the human brain is much, much more efficient than the modern computer."

Neuromorphic computing—also known as brain-inspired computing—uses an emerging post-CMOS (complementary metal oxide semiconductor) device called a memristor crossbar to essentially mimic how neurons can accomplish both tasks simultaneously.

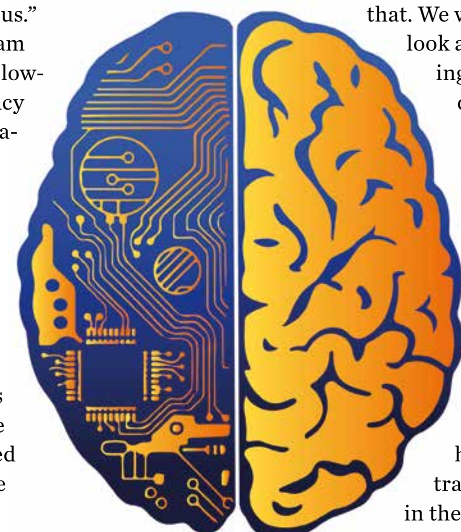
The device makes neuromorphic computing systems more efficient and enables on-device intelligence in pervasive edge and Internet of Things platforms with stringent resource limits. But to date, they've been highly unreliable in programming, reading, and retaining the data because of the immature fabrication process. Left unchecked, they can introduce errors that can accumulate when running a deep learning task and eventually lead to inaccurate results.

Wen and his team are building a self-healing framework that integrates a test, diagnosis, and recovery loop that will maintain the health of next-generation AI hardware accelerators built upon these devices.

"We've developed a very scalable method to address these issues, and make the computation in these emerging devices more reliable and sustainable," he says.

His second project (now complete) was focused on developing defense solutions to ensure the security of artificial intelligence systems.

"AI is great, but it's also dangerous," Wen says. "The human eye can easily recognize a stop sign, but an image of a stop sign that has a scratch on it could be misclassified as the speed limit by the AI. And because so many vendors like Google allow users to upload data to a cloud platform, attackers could introduce abnormal data or inject malicious intent into the AI model and destroy it. So if you have an application like a self-driving car that accesses the cloud for decision-making, the result could be disastrous."



He and his team developed a new low-cost, high-accuracy safeguarding paradigm by directly rooting the defense into compression techniques that are necessary for efficient AI processing in hardware. In this way, the resource overhead incurred by defense can be minimized.

Wen's third project explores techniques to better harness AI for future applications, such as medical imaging diagnosis and edge computing. Images like CAT scans, for example, are enormous, and sending them to a processing unit—like an edge server—could take longer than the time it takes to compute the image.

"We're thinking that in the future, you're going to have a lot of resource-limited devices," says Wen. "And these devices need to communicate with the server or with the cloud to do some kind of machine learning inference service. Traditionally, the focus has been on the inference, or the computation side. But people have ignored the communication side. It can take more than 10 seconds to send data from your sensor to the processing unit, and if your computation in the cloud takes only 5 milliseconds, that's a big issue. And we are actually the first ones to examine it."

The ideal, he says, is end-to-end low latency, especially for real-time machine learning services, like collision avoidance applications in vehicles. So Wen and his colleagues developed new compression frameworks to dramatically reduce the latency between computation and communication.

"The existing image compression frameworks are designed for the human eye, which is more sensitive to the low-frequency components," he says. "But machine learning systems are not like that. We were the first ones to look at this issue by examining the image perception difference between human vision and machine vision. And we were able to develop a new compression framework that lowered the communication window by four to five times."

It's all work that has the potential to translate into regular use in the real world, exactly in line with Wen's mission and philosophy as a researcher. His methods are inclusive of both hardware and software, and honing that range of expertise is something he stresses for his students.

"Computer engineering requires so much knowledge. It's not just the programming. It's learning both the software and hardware components," he says. "That's what I tell my students. And when they develop that level of experience, they're able to get hired by these big companies and solve practical engineering problems that have a real impact on society."

SHUTTERSTOCK/LYOLIK84

LEHIGH UNIVERSITY

P.C. Rossin College of
Engineering and Applied Science
19 Memorial Drive West
Bethlehem, PA 18015

Non-Profit Org.
US Postage
PAID
Permit No 504
Lehigh Valley PA

DISSOLVING BOUNDARIES

With a shared focus on sustainability, new faculty members (from left) Gabrielle String, Maryam Rahnemoonfar, and Farrah Moazeni expand Lehigh's research footprint.

See page 16