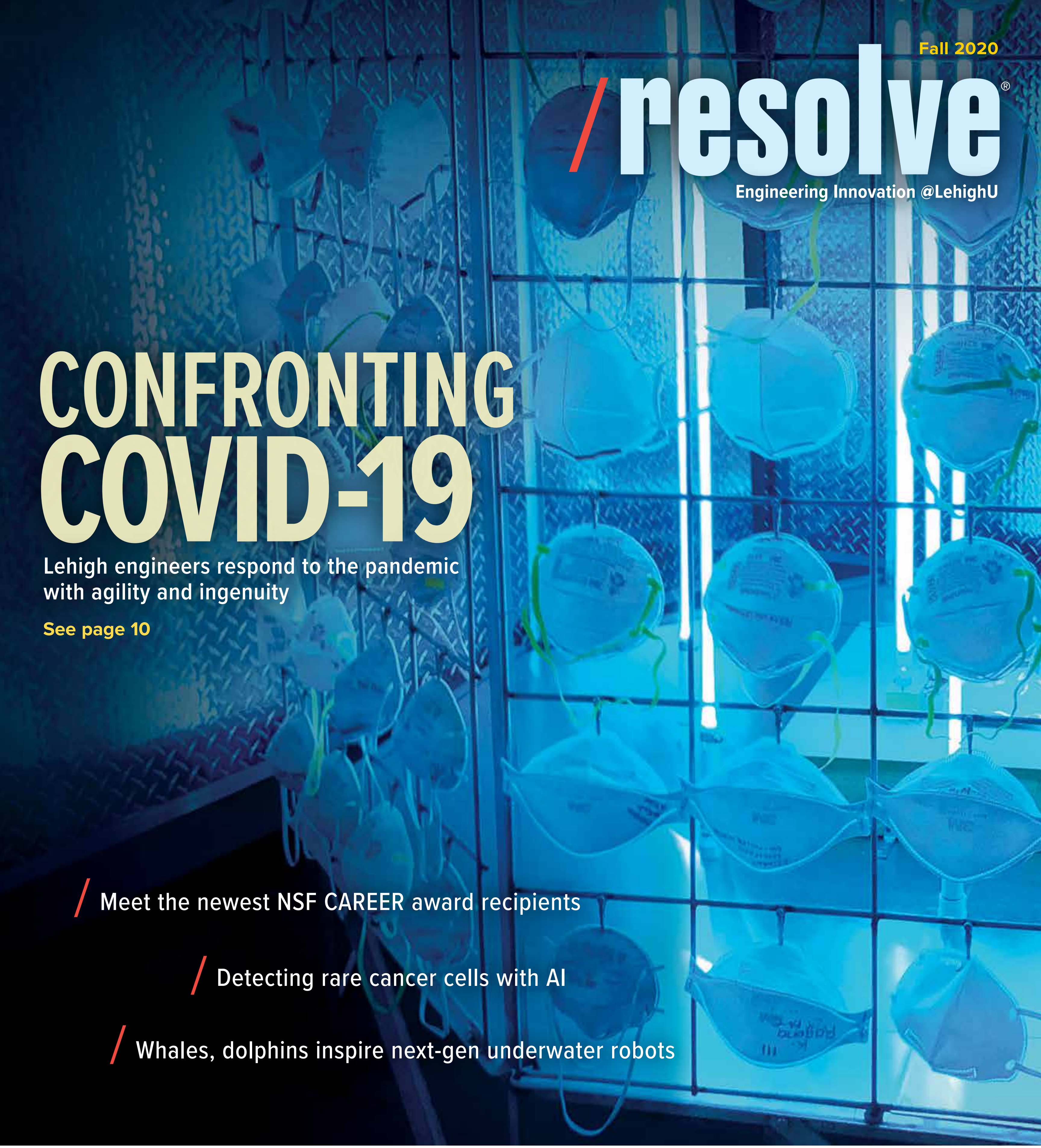

Fall 2020

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CONFRONTING COVID-19

Lehigh engineers respond to the pandemic with agility and ingenuity

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/ Meet the newest NSF CAREER award recipients

/ Detecting rare cancer cells with AI

/ Whales, dolphins inspire next-gen underwater robots

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

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LEHIGH UNIVERSITY

Inspired and taking action

Welcome to the Fall 2020 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.

When the Spring 2020 issue went to print in late February, we had but an inkling of what was to come with the growing threat of the COVID-19 pandemic, which upended our world a few weeks later. For the past six months, the breakfast bar of my home has served as the backdrop for communicating and collaborating with faculty, staff, students, and colleagues in some new, sometimes challenging, and certainly unexpected ways.

The current issue of our magazine focuses on our community's response to this ongoing crisis. Although these are troubling times, I have been inspired by the speed with which research teams pivoted their expertise to battle the virus and its many associated issues. Even as campus seemingly "went dark," there was action, as evidenced by the distinctive whine of our 3D printer labs churning out protective equipment for local frontline health care workers. Today, as we adjust to a new normal, I continue to be amazed by the creativity of our faculty and the resilience of our students in taking on the challenges of remote learning.

Our alumni, in their roles as researchers, community volunteers, and business leaders, have also contributed in innumerable ways. I invite you to check out the Rossin College News Center (*engineering.lehigh.edu/news*) for many highlights and examples of their valued efforts.

I'd like to specifically express the college's gratitude to alums Al Diaz at Intel, Ann Tracy at Colgate-Palmolive, and Scott Willoughby at Northrop Grumman; each hosted a very well-received webinar, primarily aimed at our incoming students, over the summer. The goal was to help these new Lehigh engineers feel connected to our community, supported in their decision to take on collegiate studies in the midst of the pandemic, and excited about the possibilities of a future in engineering.

This spring, our college also launched a podcast, *Rossin Connection*, as a way to help our learning community remain connected throughout the campus closure and beyond. New episodes are posted regularly on a wide variety of topics; if you have yet to download and listen, please do. I know you'll be inspired.

I CONTINUE TO BE AMAZED BY THE **CREATIVITY** OF OUR FACULTY AND THE **RESILIENCE** OF OUR STUDENTS IN FACING THE CHALLENGES OF THIS CRISIS.

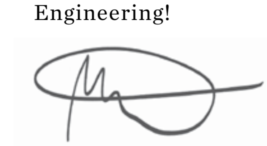
Dr. David Adinaro, a graduate of Lehigh's Healthcare Systems Engineering professional master's program, is the focus of a podcast episode and is featured in the Q&A article on page 8. His role with the federal emergency COVID convalescent facility at the Meadowlands Exposition Center and his new position with the New Jersey Department of Health exemplify the power of injecting engineering and systems thinking into the delivery of medical care.

Our university's innovative Lehigh@NasdaqCenter in the heart of San Francisco, featured on page 22, develops meaningful interaction among our students and the academic, industrial, financial, technological, and media interests that have converged around Silicon Valley. The staff and alumni who support this initiative came together to steer the entrepreneurially minded students under their watch toward successful summer internships, effectively working around the challenges of the pandemic to deliver value to the students and our partnering firms.

Although we are proud of our community's response to the many facets of the COVID crisis, it is important to note that the "regular" work of our institution continues, as evidenced by a slate of other good news we share in this issue.

In particular, on page 18, we celebrate the four emerging faculty all-stars who have earned the prestigious NSF CAREER award in 2020. In the Rossin College, 30 percent of active faculty have earned this national-level award since its inception, including 11 successful CAREER bids since 2018. The sheer magnitude of Lehigh's success in this award over the years continues to highlight the excellence of the faculty across the Rossin College.

I hope you enjoy this issue of *Resolve*; please drop me a note to share your thoughts and comments. Thank you as always for your interest in Lehigh Engineering!



Stephen P. DeWeerth, *Professor and Dean*
P.C. Rossin College of Engineering and Applied Science
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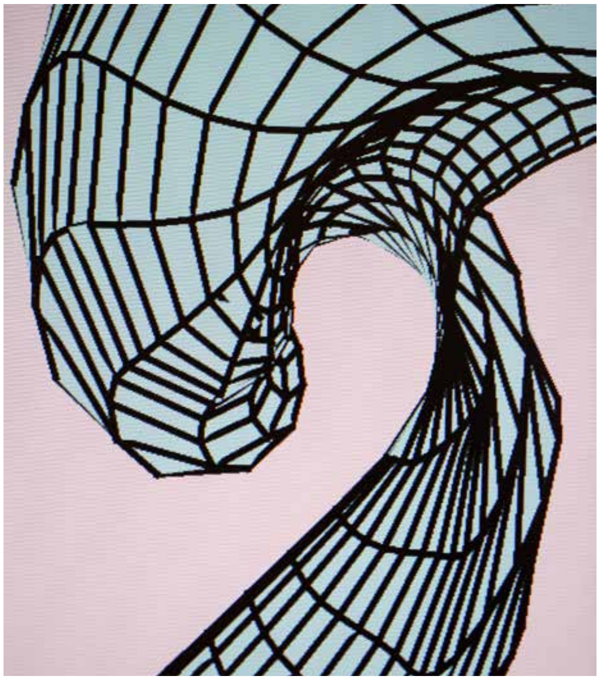
A fin-tastic model

Keith Moored is unlocking secrets to swimming efficiency of whales, dolphins for next-gen underwater robots

Someday, underwater robots may so closely mimic creatures like fish that they'll fool not only the real animals themselves but humans as well. That ability could yield information ranging from the health of fish stocks to the location of foreign watercraft.

Such robots would need to be fast, efficient, highly maneuverable, and acoustically stealthy. In other words, they would have to be very much like bottlenose dolphins or killer whales.



The wake structure left behind by a swimming dolphin depicted by using the team's numerical simulation framework

"We're interested in developing the next generation of underwater vehicles, so we're trying to understand how dolphins and whales swim as efficiently as they do," says Keith W. Moored, an associate professor of mechanical engineering and mechanics.

Moored's team recently published a paper in the *Journal of the Royal Society Interface* that examined the fluid mechanics of cetacean propulsion by numerically simulating their oscillating tail fins. For the first time, the researchers were able to develop a model that could quantitatively predict how the motions of the fin should be tailored to its shape to maximize its efficiency. The research was part of a larger $7 million multi-university project supported by the Office of Naval Research (ONR).

The tail fins of whales and dolphins come in a variety of shapes. The way cetaceans move their fins, or their kinematics, also varies. Some may flap their fins at a greater amplitude, or pitch them at a steeper angle. Moored and his team wanted to better understand this interplay between the two variables to determine if tail fin shape was tailored to a specific set of kinematics.

Using the shape and kinematic data for five cetacean species (with common names of bottlenose dolphin, spotted dolphin, killer whale, false killer whale, and beluga whale), they ran simulations on each of the species to determine its propulsive efficiency. Then they swapped the data around, for example, running a simulation on the fin shape of a killer whale attached to the kinematics of a dolphin.

"We ran 25 of these swapped simulations, and we were really surprised," says Moored. "The pseudo orca fin shape was always the most efficient. It didn't matter what kinematics we gave it. And the beluga whale kinematics were always the best, regardless of which shape it was attached to. We didn't expect that, so we started digging into it more and developed this relatively simplistic model of how efficiency scales with different kinematic and shape variables."

The model worked well to capture the data that Moored and his team had already generated, so they extended their data set to examine any resulting trends. They found that their model not only predicted efficiency beyond their data set but also revealed that specific shapes were tailored to specific kinematics.

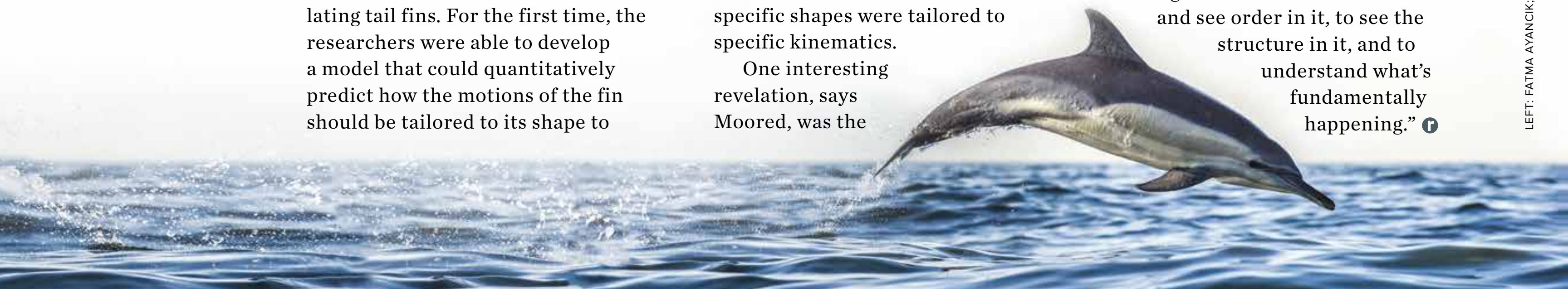
One interesting revelation, says Moored, was the fundamental interplay between circulatory forces and added mass forces that contribute to an animal's movement. Circulatory forces are those that generate lift, like with aircraft.

"A tail that's flapping up and down generates forces just like an aircraft, but it also generates added mass forces that have to do with how fast the fluid is being accelerated," says Moored. "In the past, people didn't think those added mass forces were that relevant in cetacean swimming. But we found that the accelerations of the fin are integral to predicting the trends of efficiency. It ultimately gives us a predictive model that's accurate. Without it, we'd basically be saying that fin shape doesn't change the efficiency, and that's not true."

Having a model that can predict performance based on shape and kinematics provides a basic design equation of sorts for building an underwater robot that performs like a cetacean. To date, these equations haven't existed. And the potential for these machines is huge. Fast, efficient, and highly maneuverable fish-shaped robots could help researchers test hypotheses about how the animals swim, and better understand the behavior of fish schools. They could be used to detect submarines and other submersibles. They could also be used to monitor the impact of climate change on fish stock populations.

Moored and his team have already expanded their scaling model to account for a larger range of variables they then validated with experimental data. Ultimately, they want to build one that captures the effects of these variables, and can then predict performance for a range of applications.

"This fish swimming problem is a really exciting problem because it's so complicated," he says. "It's fascinating to take this chaos of variables and see order in it, to see the structure in it, and to understand what's fundamentally happening."



LEFT: FATMA AYANCIK; BOTTOM: SERGEY URYADNIKOV/SHUTTERSTOCK

Research into nitrogen-efficient fertilizers envisions lasting effects

The world's population will continue to grow, but the amount of arable land to feed that population will not.

"So people will continue to add more fertilizers to grow more crops in the same areas," says Jonas Baltrusaitis, an associate professor of chemical and biomolecular engineering. "You can't grow crops without fertilizer. It's just not happening."

While a boon to harvests, fertilizers exact a toll on the environment. Their production alone is extremely energy intensive and a significant source of greenhouse gases, and when nutrients like nitrogen and phosphorus aren't fully taken up by plants, they can leach into groundwater and wash into waterways. Excess nutrients can cause eutrophication of water bodies where algal blooms deprive the ecosystem of oxygen, killing wildlife and producing toxins that can harm humans.

It's a vicious cycle that Baltrusaitis, who recently received a four-year, nearly $435,000 grant through the USDA's National Institute of Food and Agriculture, hopes to one day break.

His team has developed a dry mechanochemical synthesis method of a family of urea ionic cocrystals that can serve as functional fertilizers that significantly slow down urea hydrolysis in soil, reduce ammonia emissions, and extend availability of nitrogen to plants. He is combining water-soluble urea with various nutrients containing low-solubility minerals or even industrial waste, such as drywall gypsum, to improve nitrogen management efficiency.

"We're redesigning fertilizer materials to be much more stable in the environment," he says. "If they don't decompose as fast, they're available to the plant for longer, so those nutrients are going into the food chain rather than being wasted and damaging the environment."

The potential impact is global, and the technology is being developed to be easily inserted into existing supply chains, says Baltrusaitis. His ultimate goal is to design nitrogen-efficient novel fertilizer materials that can be used in field trials with local Pennsylvania farmers, in which his team can test improvements in yields and emissions.

THE POTENTIAL IMPACT IS **GLOBAL**, AND THE TECHNOLOGY IS BEING DEVELOPED TO BE EASILY INSERTED INTO **EXISTING SUPPLY CHAINS.**

—Jonas Baltrusaitis

FOTOKOSTIC/SHUTTERSTOCK

RESEARCH RECOGNITION

PROFESSIONAL, SCIENTIFIC HONORS HIGHLIGHT FACULTY IMPACT

» Civil and environmental engineering professor **Dan M. Frangopol** has been elected to the National Academy of Construction, an elite institution that recognizes individuals from all sectors of the built environment who have made extraordinary contributions to the construction industry.

» Materials science and engineering professor **Christopher J. Kiely** has been elected as a Fellow of the Microanalysis Society. He was honored for "outstanding leadership and sustained contributions to analytical electron microscopy of nanoparticle self-assembly, metal and complex oxide catalysts, and interfacial analysis."

» Mechanical engineering and mechanics professor **Donald O. Rockwell** has been elected as a Fellow of the American Institute of Aeronautics and Astronautics. He was commended for his "breakthrough insight into unsteady aerodynamic flows and structural interactions using novel experimental approaches and advanced image processing" as well as his "technical leadership and educational achievements."

» Industrial and systems engineering professor **Tamás Terlaky** has been elected to the Canadian Academy of Engineering. He previously served as Canada Research Chair in Optimization at McMaster University in Ontario, where he was also founding director of its School of Computational Engineering and Science.

A breakthrough in developing multi-watt terahertz lasers

New technique achieves record-high output power

Terahertz lasers could soon have their moment.

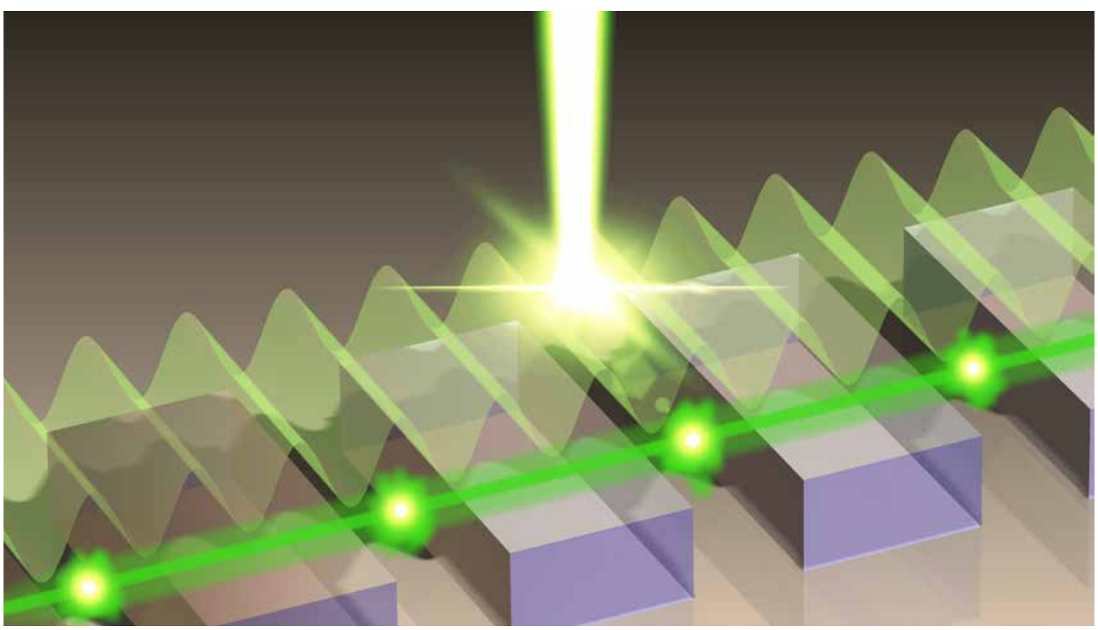
Emitting radiation that sits somewhere between microwaves and infrared light along the electromagnetic spectrum, terahertz lasers have been the focus of intense study for a number of potential applications: They're able to penetrate common packaging materials, such as plastics, fabrics, and cardboard. They can be used for identification and detection of various chemicals and biomolecular species. They can even image some types of biological tissue without causing damage.

Fulfilling their potential hinges on improving their intensity and brightness, achieved by enhancing power output and beam quality. Sushil Kumar, an associate professor of electrical and computer engineering, and his team are working at the forefront of terahertz semiconductor "quantum-cascade" laser (QCL) technology.

In 2018, Kumar reported on a simple yet effective technique to enhance the power output of single-mode lasers based on a new type of "distributed-feedback" mechanism that was seen as a major advance. Graduate students supervised by Kumar, including Yuan Jin, worked in collaboration with Sandia National Laboratories.

Now, Kumar, Jin, and John L. Reno of Sandia are reporting another breakthrough: They have developed a new phase-locking technique for plasmonic lasers and, through its use, achieved a record-high power output for terahertz lasers. Their laser has produced the highest radiative efficiency for any single-wavelength semiconductor QCL to date, which is a significant result in itself given that the QCLs were invented more than two decades ago and further performance improvements have been difficult to come by. A paper explaining the results was recently published in *Optica*.

"To the best of our knowledge, ours is also the first report of a radiative efficiency of greater than 50 percent achieved in such QCLs," says Kumar. "Such a high radiative efficiency beat our expectations, and it is also one of the reasons why the output power from our laser is significantly greater than what has been achieved previously."



Rendering of a phase-locking scheme for plasmonic lasers in which traveling surface waves longitudinally couple several metallic microcavities

ILLUSTRATION: YUAN JIN/LEHIGH UNIVERSITY

To enhance the optical power output and beam quality of semiconductor lasers, scientists often utilize phase-locking, an electromagnetic control system that forces an array of optical cavities to emit radiation in lockstep. Terahertz QCLs, which use optical cavities with metal coatings (claddings) for light confinement, are a class of lasers known as plasmonic lasers that are notorious for their poor radiative properties. There are only a limited number of techniques available in prior literature, according to the team, that could be utilized to improve radiative efficiency and output power of such plasmonic lasers by significant margins.

> SUCH A HIGH RADIATIVE EFFICIENCY **BEAT OUR EXPECTATIONS**, AND THE OUTPUT POWER IS **SIGNIFICANTLY GREATER** THAN WHAT HAS BEEN ACHIEVED.
>
> —Sushil Kumar

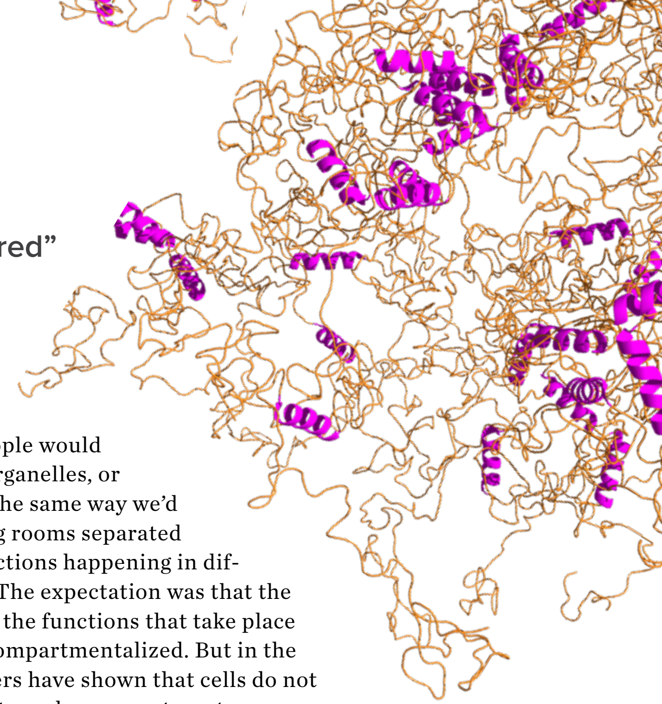
"Our scheme is distinctly different," says Jin. "It makes use of traveling surface waves of electromagnetic radiation as a tool for phase-locking of plasmonic optical cavities. The method's efficacy is demonstrated by achieving record-high output power for terahertz lasers that has been increased by an order of magnitude compared to prior work."

Traveling surface waves that propagate along the metal layer of the cavities, but outside in the surrounding medium of the cavities rather than inside, is a unique method that has been developed in Kumar's group in recent years and one that continues to open new avenues for innovation. The team expects that the output power level of their lasers could lead to collaborations between laser researchers and application scientists toward development of terahertz spectroscopy and sensing platforms.

This research represents a paradigm shift in how such single-wavelength terahertz lasers with narrow beams are developed and will be developed going forward, says Kumar. "I think the future of terahertz lasers is looking very bright."

Zeroing in on TDP-43

Research team seeks clearer understanding of "intrinsically disordered" protein that holds promise for ALS, Alzheimer's treatments



Simulations of TDP-43 run by Mittal's lab, represented in this illustration, help inform the design of experiments conducted in Fawzi's lab.

On the surface, amyotrophic lateral sclerosis (ALS) and Alzheimer's disease share two commonalities: Both are progressively debilitating neurodegenerative conditions—meaning symptoms get worse—and, at least for now, neither has an effective treatment, let alone a cure.

On the molecular level, a recently identified connection between these devastating diseases could help advance the search for new therapies, according to Jeetain Mittal, the Sam and Ruth Madrid Endowed Chair in Chemical and Biomolecular Engineering.

Mittal and Brown University collaborator Nicolas Fawzi are focused on TAR DNA-binding protein 43, or TDP-43. Neuronal deposits of this essential human protein are found in people living with Alzheimer's and related types of dementia, as well as those diagnosed with ALS (Lou Gehrig's disease).

The research team has been awarded a $3.3 million grant from the National Institutes of Health to use their combined expertise in structural biology techniques—Fawzi's is experimental; Mittal's, computational—to visualize the atomistic details of TDP-43 assembly, explore the role of post-translational modification and disease-associated mutations on the assembly processes, and investigate interactions with several promising therapeutic targets to prevent aggregation.

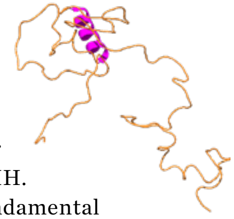
The results of Mittal and Fawzi's earlier work on TDP-43 have been published in *Proceedings of the National Academy of Sciences* and *Structure*. "Our previous research is only the tip of the iceberg," says Mittal. "The next step is to take a look at the actual mutations associated with ALS and Alzheimer's and get to the bottom of how they affect the assembly of TDP-43 to give us a better understanding of what causes their malfunction. Then, we can support researchers developing new therapeutic strategies."

TDP-43 has two sides—one end of the molecule is made up of tightly packed folded regions, while the other side is classified as an intrinsically disordered region (IDR) because parts of it lack a well-defined structure. Mittal, a biophysicist, has a longstanding interest in IDRs and has developed simulation methods to help visualize how these proteins fold or misfold, potentially leading to disease-related aggregation in the body.

The unorganized nature of IDRs such as TDP-43 facilitates the formation of membrane-less organelles within cells through a process called liquid-liquid phase separation, a phenomenon that, according to Mittal, "has taken the biology world by storm."

"Not all that long ago, people would think about a formation of organelles, or compartments within cells, the same way we'd think about a building having rooms separated with walls, and different functions happening in different rooms," he explains. "The expectation was that the information within cells and the functions that take place inside of them were highly compartmentalized. But in the past 10 or 12 years, researchers have shown that cells do not require walls or membranes to make compartments.

"With liquid-liquid phase separation, you have a well-mixed solution of biomolecules, proteins, RNA, and so forth that suddenly coalesce in these very dense, liquid-like droplets. But if something goes wrong, and they don't form properly, these granules become more solid-like and prone to aggregation."



TDP-43 is a well-known component of these granules, he says, and because of the known genetic and other links to ALS, frontotemporal dementia, and Alzheimer's disease, further study is of interest to the NIH.

The team is pursuing fundamental questions about the protein's structure through two different but complementary approaches: Fawzi's lab conducts highly sophisticated nuclear magnetic resonance experiments, confirming the protein's loose, noodle-like structure through numerous readings averaged together. Mittal's lab runs physics-based simulations that provide detailed spatial and time-related information and can predict how mutations to TDP-43 might affect phase behavior in the formation of membrane-less organelles.

"CHANGING JUST A **FEW** ATOMS OUT OF HUNDREDS OR THOUSANDS WITHIN THE PROTEIN CAN AFFECT ITS **FUNCTION**, **ASSEMBLY**, AND **INTERACTIONS**." —Jeetain Mittal

Combining these methods allows the researchers "to get a mechanistic sense of how each step, from the atoms to the molecules to the single-protein level, connects," Mittal says.

"Changing just a few atoms out of hundreds or thousands within the protein can affect its function, assembly, and interactions, so having a complete picture is important. Otherwise you're just throwing everything at it and seeing what works. We're trying to gain a better understanding so we can target our approach in a predictive manner."

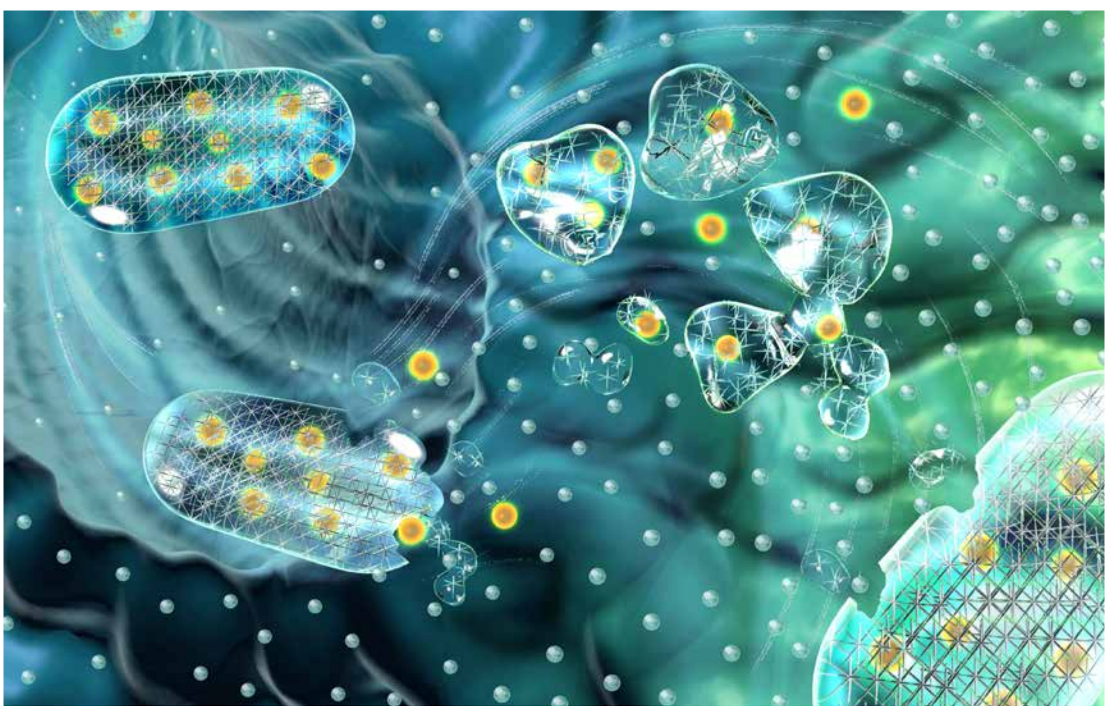
ILLUSTRATION: BIOPHYSICS AND SOFT MATTER GROUP AT LEHIGH UNIVERSITY; PHOTO: RYAN HULVAT

Better oral drug delivery could take shape with innovative gel

Rheologists mimic pH conditions of GI tract to study CAHs

An emerging hydrogel material that has the capacity to degrade and spontaneously reform in the gastrointestinal tract could help researchers develop new and more effective methods for oral drug delivery.

“The majority of drugs and nutrients are absorbed into the body in the intestines, but to get there, they have to traverse the stomach, which is a very acidic, harsh environment that can interfere with the active molecules in pharmaceuticals,” says Kelly Schultz, an associate professor in the Department of Chemical and Biomolecular Engineering.



An artistic rendering shows CAH degradation in response to pH changes over time that replicate the GI tract.

ILLUSTRATION BY SAYO STUDIO LLC

Schultz and fourth-year chemical engineering PhD student Nan Wu are studying covalent adaptable hydrogels (CAHs), which are being designed to release molecules as they lose polymer in the stomach but then re-gel on their own, which protects the molecules and allows them to stay active for targeted delivery in the intestines. The team’s microrheology research was recently published in *Soft Matter*.

To characterize the material and provide insight into its pharmaceutical potential, Wu has repurposed a microfluidic device originally developed in Schultz’s lab for research into fabric and home care products to create a “GI tract-on-a-chip.” The experimental setup allows her to exchange the fluid environment around the gel to mimic the pH environment of all the organs in the GI-tract, simulating how the material would react over time if ingested.

Using microrheology, Wu collects microscopy data and measures how much particles within the gel wiggle, with some experiments taking hours and others spanning days, depending on the digestive organ she is replicating. She tracks the particles using an algorithm that yields scientifically meaningful information on the properties of the material, which was originally developed by University of Colorado at Boulder chemical and biological engineering professor Kristi S. Anseth.

“Covalent adaptable hydrogels exhibit unusual spontaneous re-gelation that is really surprising,” Schultz says. “Typically, gels won’t degrade and then reform without any added stimuli as these do. We’ve demonstrated viability of CAHs as means of oral drug and nutrient delivery, and now we’re starting to work on molecular release studies and adding in other components to make the experiments more complex.”

Wu has been investigating these materials over the course of her entire PhD studies, says Schultz. “She’s doing amazing work and is committed to understanding every aspect of the research.”

Schultz’s lab focuses on the characterization of colloidal and polymeric gel scaffolds and the development of new techniques to characterize these complex systems, which play important roles in fields such as health care and consumer products.

“A GREAT DEAL OF MYSTERY LIES BETWEEN **DESIGNING** A MATERIAL AND **UNDERSTANDING** WHAT’S GOING ON WHEN IT’S WORKING.”

—Kelly Schultz

“What we do in biomaterials is somewhat unique,” Schultz says. “There’s a lot of work on the cross-linking chemistry and actually developing these materials, and there’s a lot of animal research that implants and tests them, but there’s not that much work in the middle.

“A great deal of mystery lies between designing a material and understanding what’s going on when it’s working. We’re trying to find new ways that we can replicate what’s going on inside of an animal or a person and collect important measurements to connect the dots and inform further studies.”

Neural network approach streamlines detection of rare cancer cells

Metastasis—the development of tumor growth at a secondary site—is responsible for the majority of cancer-related deaths. It occurs when the primary tumor site sheds cancerous cells that are then circulated through the body via blood vessels or lymph nodes. These become seeds for eventual tumor growth at a secondary area in the body.

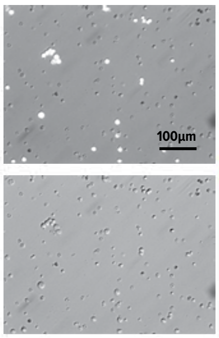
Detection of these very rare cells, known as circulating tumor cells, or CTCs, is important for early prognosis of serious disease as well as to monitor the effectiveness of treatment. Currently, only one method for CTC detection is approved by the FDA, and it relies on an expensive, time-consuming process that involves labeling antibodies with fluorescence.

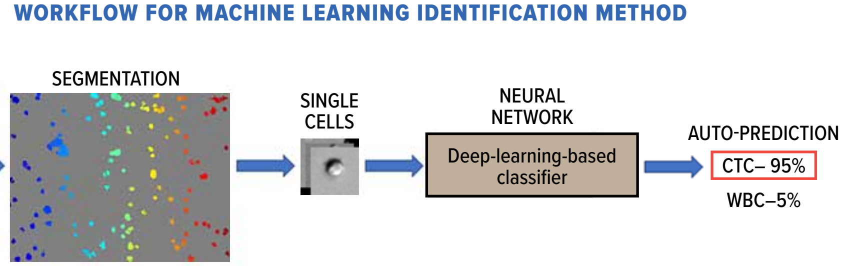
Results from a recent study show the potential for a new way to detect CTCs that uses a powerful label-free detection method. Developed by bioengineering and mechanical engineering and mechanics professor Yaling Liu, in collaboration with Xiaolei Huang, a faculty member in Penn State's College of Information Sciences and Technology, the technique applies a machine learning algorithm to bright field microscopy images of cells detected in patient blood samples containing white blood cells (WBCs) and CTCs.

The blood samples were drawn from patients in treatment for stage 4 renal cancer under the care of Dr. Suresh G. Nair, physician in chief at Lehigh Valley Cancer Institute. The model yielded a high rate of accuracy: 88.6 percent overall accuracy on patient blood and 97 percent on cultured cells. The results have been published in *Nature Scientific Reports*. In addition to Liu, Huang, and Nair, authors include three Lehigh PhD students: Shen Weng, Yuyuan Zhou, and Xiachen Qin.

Nair says Liu's innovative technique to isolate rare circulating cancer cells in a tube of blood—which can number as few as 15 cells in one billion—represents "a simpler, elegant, and cost-effective approach to monitoring patients on therapies such as immunotherapy and targeted therapy for cancer at the circulating cell level rather than scans such as CAT scans, which look for 100 million or more cells organized into a one centimeter tumor."

"This study, though small, demonstrates that our method can achieve high accuracy without the need for advanced devices or expert users, thus providing a faster and simpler way for counting and identifying CTCs," says Liu. "With more data becoming available, the machine learning model can be further improved and serve as an accurate and easy-to-use tool for CTC analysis."





A deep-learning model was trained with cropped single-cell in bright field images and tuned "to reach better results until the outcome reached the state-of-the-art," says Liu.

FIGURE BY SHEN WANG/LIU RESEARCH LAB; TOP PHOTO: DOUGLAS BENEDICT/ACADEMIC IMAGE

RAMAMURTHI TAKES HELM OF BIOENGINEERING

Anand Ramamurthi, an expert in platform technologies for *in situ* elastic tissue repair and *in vitro* tissue engineering, has joined Lehigh as P.C. Rossin Professor and Chair of the Department of Bioengineering, succeeding Founding Chair Anand Jagota.

Ramamurthi comes from the Lerner Research Institute of the Cleveland Clinic, where he was a professor of biomedical engineering. He was also a professor of molecular medicine and biomedical engineering at the Cleveland Clinic Lerner College of Medicine of Case Western Reserve University. His research focuses on enabling biomimetic regeneration and repair of elastic fibers and superstructures that do not naturally regenerate or repair in elastic adult tissues.

"Dr. Ramamurthi brings a wealth of biomedical expertise and leadership," says Stephen P. DeWeerth, dean of the Rossin College. "His research directions are particularly well matched to Lehigh initiatives in biomedicine, engineered materials, and health."

"Having conducted research at institutions closely associated with centers of medical excellence, I am committed to propagating the translational aspect of biomedical research at Lehigh," says Ramamurthi, who is a Fellow of the American Heart Association and serves as executive editor of the *Journal of Tissue Science and Engineering*. "I look forward to establishing a cutting-edge research program in stem cell and nanomedicine for extracellular matrix engineering and repair."

RELIEVING THE PRESSURE

ER doc and healthcare systems engineer David Adinaro on caring for the 'COVID convalescent'

Dr. David Adinaro '88 '15 M.Eng. was recently named deputy commissioner for public health services for New Jersey's Department of Health. An emergency medicine physician and alumnus of Lehigh's Healthcare Systems Engineering graduate program, Adinaro was tapped for this role after answering the call to lead the NJ Field Medical Station-Secaucus at the Meadowlands in the early months of the pandemic. As its chief medical officer (CMO), Adinaro guided the convention-center-turned-field-hospital and its volunteer medical staff in its mission to care for recovering COVID-19 patients while taking stress off of hospitals. Prior to his public service, Adinaro held numerous positions, including chief of emergency medicine, chief medical information officer, and vice president and CMO, over his 17-year career as a physician at New Jersey's St. Joseph's University Medical Center.

Q: How did the field hospital get started?

A: When I arrived at the Meadowlands Exposition Center, 250 cubicles had been erected to serve as patient rooms. Over the next eight days, and with support from the state's National Guard, Office of Emergency Management, and additional partners, we found staff, got radiology and lab support, and gathered all the equipment you need to be a stripped-down community hospital.

At the beginning, we were tasked with creating a facility for non-COVID patients because the hospitals were overwhelmed. But by the time we were up and running on April 8, there were almost no non-COVID patients in hospitals. So, we switched gears to focus on the "COVID convalescing"—people in the final three to seven days of their hospital stay.

Nearly all of our patients required oxygen, and setting that up was a bit of an engineering feat. Hospitals have sophisticated medical gas systems and big tanks of liquid oxygen. We had to supply our oxygen through many heavy, smaller steel tanks. I worked with the respiratory therapist to calculate how much oxygen we needed on a daily basis and what that translated to in terms of portable tanks. And by portable, I mean they weigh 140 pounds each! Also, how much tubing? How many regulators and mutilators? There was a little bit of engineering and a lot of math, which is not a normal CMO type of thing.

Q: Could you describe your team and what it was like working there?

A: At the time, there weren't a lot of elective surgeries going on, so those doctors joined our staff. For example, we had a plastic surgeon, a husband-and-wife pediatrician-and-spine-surgeon combo, and a vascular surgeon who does outpatient vein procedures. A 25-person medical

TOP: KATIE KACKENMEISTER

Dr. Adinaro's training as a physician, administrator, and systems engineer prepared him for the challenges of leading the medical operations of a field hospital (below) in a New Jersey expo center.

THIS PAGE AND OPPOSITE PAGE INSET: COURTESY OF DAVID ADINARO

contingent of New Jersey Army and Air National Guard personnel was also key to our initial success. There were many physician assistants and advanced-practice nurses, but none of these people had been practicing hospital-based medicine just a few weeks prior.

It was an austere environment. People working with patients wore scrubs, plus an impregnable gown, a N95 mask, a surgical mask, and an eye shield, for 11 hours of a 12-hour shift. You'd sit on metal chairs with tables like you'd have at a picnic. You were working on paper. The patient rooms were 10-by-10 cubicles with a curtain. They had electricity, a lamp, a camp bed, pretty good Wi-Fi, another chair, and a little table. It was designed to be temporary, and in May, with the "curve" of cases improving, the entire operation moved to a former acute rehabilitation hospital in East Orange. Fortunately, no patients are currently there, but it is ready to be reactivated within days should a second wave of patients occur.

Q: How would you characterize your specific role as CMO?

A: In Secaucus, we were practicing least-common-denominator, commonsense medicine. But there are some things you just have to do right. We had to be prepared for a medical emergency. We required a lot of PPE [personal protective equipment] to keep everybody safe. And we also needed to have procedures in place if a staff member were to get sick.

As CMO, I was in charge of provider relations, screening of the physicians, troubleshooting, and any patient care issues that came up. I worked with the physicians to establish a cohesive approach. I also spent a lot of time interacting with the National Guard command and the Department of Health, coordinating with the acute care hospitals and deciding which patients we could accept.

Q: How did your medical experience prepare you for this job?

A: Having been an emergency physician for a long time, I'm used to a less well-defined environment. I also have a background in large projects. The challenge was that we were operating with few people in an extremely short period of time and had to make decisions in days, not months. But having project management expertise, knowing how to work with people from different backgrounds, being familiar with the state police and their resources, and understanding the bare minimum needed to run a hospital all prepared me for this role.

Q: Where did your engineering background tie in?

A: A lot of what I was doing was pure engineering or troubleshooting on the systems side. I was constantly figuring out where the rate-limiting steps were. Getting the hospitals to know what patients we'd take. Then arranging for the patients to show up, and making sure they weren't all arriving at the same time. And then, how would we get them home again? These were all steps in the system, and if there were a failure at any point, it would back up everybody else in the flow. I had to engineer the systems and figure out how to safely get to the easiest, fewest number of steps possible.

We needed to make it easy for the hospitals, which were bursting at the seams with people in danger of dying. If I'd asked for a complete medical record on every single patient before we'd even talk to them, they'd never send me a patient. We needed to unburden the hospitals safely with a properly trained team of professionals.

I will always feel like I'm not doing enough unless I'm in the absolute chaos of the ER. But by getting as many patients as we could out of these hospitals, we were making it possible for doctors and nurses to have better patient ratios, so they could focus on the sicker patients. And these convalescing patients received a level of attention that would have been impossible in the overwhelmed acute care hospitals.

Q: Why is a systems engineering mindset important in your field?

A: Compared with other industries like manufacturing or retail, health care is probably a generation behind when it comes to taking a systematic, technology-driven, data-analytics approach to decision-making. Obviously in health care, you're not making a widget and you don't always know what the individual patient's journey is going to be, so it's incredibly dynamic. My experience in Lehigh's Healthcare Systems Engineering program made me far better at understanding the interrelationship of parts within a complex system and applying the principles of optimization. And just like medical school made me think like a doctor, going through the HSE program changed my brain and made me think like an engineer.

LISTEN IN

Dr. Adinaro talks about his experiences on the frontlines of the pandemic on our new *Rossin Connection* podcast. Visit go.lehigh.edu/RossinConnection to subscribe (or learn how to subscribe!).

COMMON CAUSE

Amid the coronavirus shutdown, Lehigh engineers sprang into action—making an impact on COVID-19 response within the local community and across their fields of expertise

LEHIGH'S CAMPUS should have been buzzing with post-spring-break energy. Instead there was silence. Even research activities, the steady current that drives the university forward, had been forced to power down.

At least on the surface.

In the early days of the COVID-19 crisis—and continuing today—Lehigh engineers found creative ways to contribute to the community response by applying and advancing fundamental knowledge within their disciplines. They answered the call to help hospitals weather a shortage of personal protective equipment (PPE) and are exploring new ways to make disinfectants more effective. They're innovating as they pursue a better understanding of the virus and vaccines and other methods to curb its spread. They're even digging into the social ramifications of "going remote."

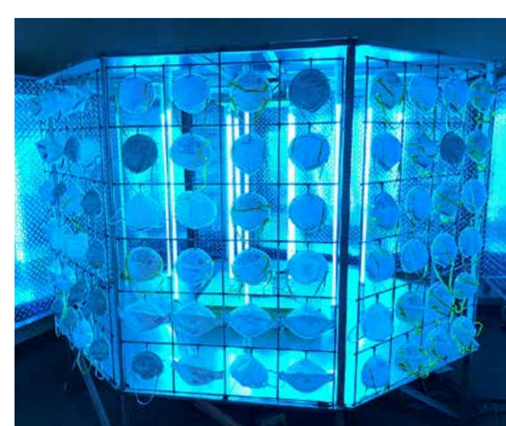
Uncertain. Unprecedented. Unique. The pandemic has proven to be all of these things. At the same time, there is reassuring familiarity in the roll-up-the-sleeves, problem-solving approach that engineers in the Rossin College are taking to rise to our present challenge.

'Bug Zapper' invention safely sterilizes N95 masks

When the request from Dr. Christopher Roscher, an anesthesiologist at St. Luke's University Health Network, hit Nelson Tansu's inbox in mid-March, his response was swift:

Yes, most likely, it could be done.

Faced with the nationwide shortage of N95 masks, St. Luke's knew it needed a safe, effective way to extend its existing supply for medical professionals treating COVID-19 patients. Roscher's personal research exploring the use of UV light for PPE decontamination in a pandemic situation led him to Tansu, the Daniel E. '39 and Patricia M. Smith Endowed Chair Professor in the Department of Electrical and Computer Engineering (ECE).



"We approached this idea understanding that in an ideal world we would have a new mask for everybody who needed one," says Roscher, "but the reality of the situation is that we need to conserve."

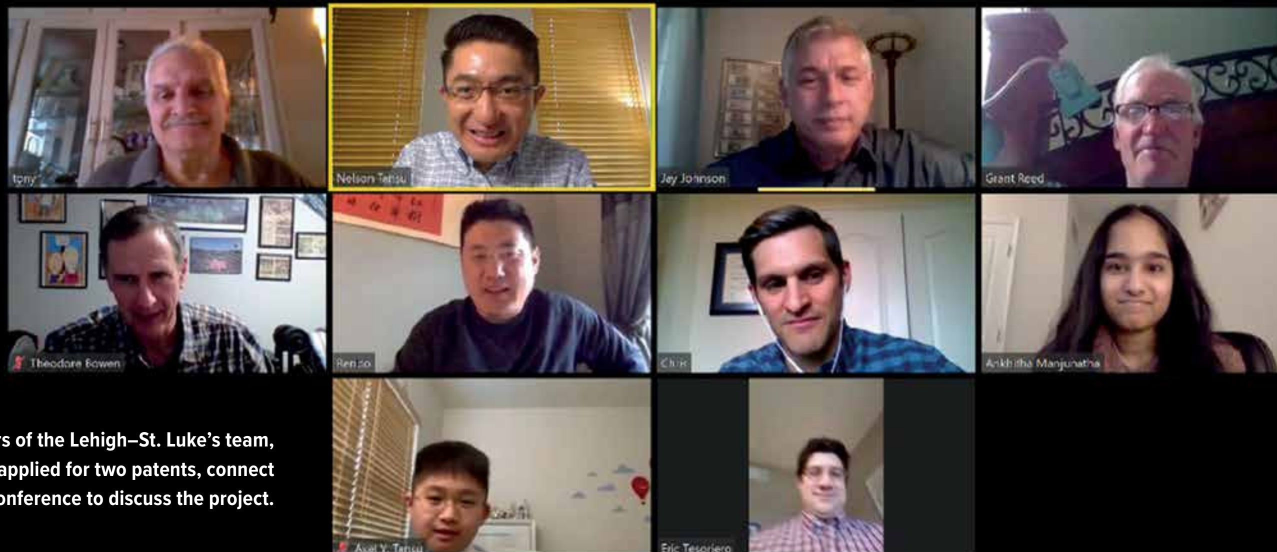
Hours after the initial email, Tansu and his colleagues discussed a potential plan with Roscher. The next day, he gathered an enthusiastic team of volunteers—staff and students from Lehigh's Center for Photonics and Nanoelectronics (CPN), where Tansu serves as director, and the ECE department, all practicing social distancing in their homes.

"If we are on board, then we can transform this idea into reality," Tansu told them. "Together with the team of doctors, we have to figure out a solution that we can build in our garages."

And that's what they did. Collaborating via Zoom meetings, phone calls, and hundreds

Additive manufacturing coordinator Trevor Verdonik, donning a full suit of protective gear as a precaution against spreading germs, works on face shield components in Wilbur Powerhouse.

LEFT: CONTRIBUTED; RIGHT: COURTESY OF ST. LUKE'S UNIVERSITY HEALTH NETWORK



Members of the Lehigh–St. Luke's team, which has applied for two patents, connect via videoconference to discuss the project.

of emails and text messages, Tansu, Roscher, and their team designed, completed the engineering fabrication of, and installed the device in less than three weeks—without ever stepping foot on Lehigh's campus or meeting face-to-face.

Now in use at St. Luke's, the "High-Throughput Symmetrical and Non-Shadowing Ultraviolet Sterilization System" (nicknamed the "Bug Zapper" because of its resemblance to the insect-killing backyard device) exposes the masks to UV-C light. This specific range of ultraviolet light can cause changes in the DNA and RNA of viruses and other pathogens, including novel coronavirus, effectively deactivating them. The team has filed two patent applications associated with the invention.

"THIS IS ONE OF THE **QUICKEST TURNAROUNDS** FROM IDEA TO EXECUTION THAT I HAVE EVER EXPERIENCED."
—Nelson Tansu

The system has a large, octagonal metal frame with UV lights positioned at its center to achieve symmetrical UV-C irradiation on the N95 masks. Its targeted capacity is approximately 3000 N95 masks per day (200 per exposure), but that figure can scale up to 10,000 masks per day if necessary.

The goal, says Tansu, was to use enough UV-C light to damage viruses and bacteria but retain the integrity of the N95 mask, which can be degraded more significantly over time by steam or chemicals. Staff members at St. Luke's monitor exposures with a radiometer, which measures the amount of light irradiation to which the masks are exposed.

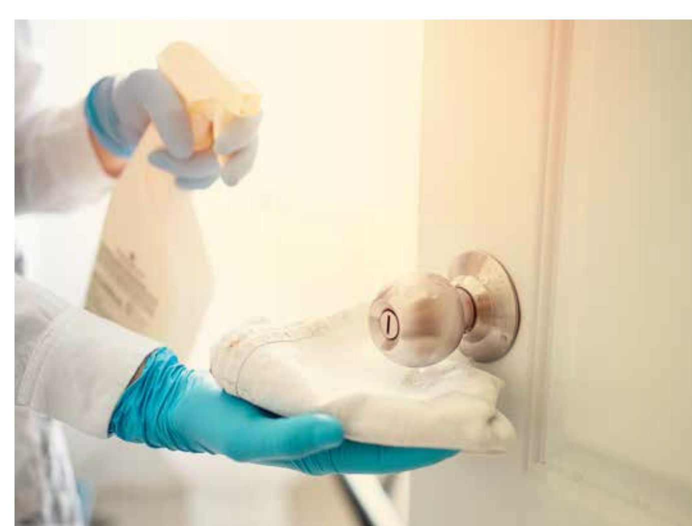
The final design—a true collaborative effort—was ready in just two days. "Everybody just kept building on the idea," says Anthony Jeffers, a research engineer in the CPN. "We were on the same level all the way through: We were just there to try and solve the problem."

To observe distancing guidelines, the team then divided the project into individual tasks that allowed them to build the device modularly from home.

"The first staff member built a certain part and the second staff member built the second part," explains Tansu. What followed, he jokes, might have seemed suspicious to a casual observer: Each team member dropped a part off in a specified location at a particular time and remained in his or her car to watch over it from afar until the St. Luke's representative picked it up. Finally, they assembled it "like a LEGO set," says Tansu.

With the remote assistance of Tansu and his team, the team at St. Luke's conducted tests to determine the appropriate dose of UV-C light, as well as microbiological tests to determine the device's effectiveness.

"Designing something, optimizing it, completing further analysis, putting together an experimental plan, creating it, testing it, and using it typically takes a very long time, a period of months, especially in academia," says Tansu, who is a Fellow of the U.S. National Academy of Inventors. "But this is one of the quickest turnarounds from idea to execution that I have ever experienced. We are very fortunate to have such a committed team in completing this important task in such a short time." *—Kelly Hochbein*



TOP: COURTESY OF NELSON TANSU/USED WITH PERMISSION; BOTTOM: THESKAMAN306/SHUTTERSTOCK

Design lab team takes on essential role in 3D printing face shields

I wish there were some way we could help the doctors and nurses in New York.

It was Brian Slocum's first thought when he read news describing how doctors were treating coronavirus patients without adequate personal protective equipment. He immediately started researching ways to solve the problem.

"And I very quickly found that people all over the world were working on either 3D-printed or custom manufactured solutions," says Slocum, who is managing director of Lehigh's Wilbur Powerhouse and Design Labs, and a Lehigh alum himself. "I thought, *I wonder if we could do that?*"

At nearly the same time, Slocum started receiving emails from local hospital administrators who were worried about their supplies of protective gear. They wanted to know if Lehigh could help them.

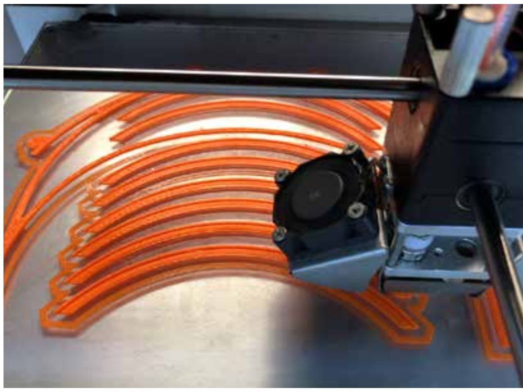
Slocum soon found an article published by Prusa Research, a Czech company that had developed a clear plastic face shield that could be 3D-printed, and was open-sourcing their design. Slocum responded to the administrators, telling them Lehigh could absolutely produce something like it.

"It prevents droplets from people coughing or sneezing from hitting the doctor's face," says Slocum. "It also increases the life of the N95 masks that providers are wearing."

Slocum, along with additive manufacturing coordinator Trevor Verdonik '13 '15G, a PhD student in materials science, and Michael Moore '12, assistant manager of the design labs, began iterating on the Prusa design. They were soon joined by the product development team at Knoll, a design firm located 20 miles from campus.

The medical professionals the team consulted with identified a few problems with the Prusa design. A gap between the forehead and the plastic face shield could potentially allow droplets in from above, and the elastic band that went around the head couldn't be cleaned properly.

To address the first problem, the Lehigh and Knoll teams designed a 3D-printed dual headband. One band rests directly against the forehead, and one sweeps out in front to hold the face shield. They designed pegs along both bands, which allowed them to secure a neoprene comfort guard that acted as both a cushion for the forehead band and a roof that closed the gap between the two bands. An adjustable, easily sanitized neoprene head strap solved the second issue.



Multiple headband iterations were 3D-printed during the prototyping step to optimize the face shield design and the production process.

Lehigh designated Slocum, Verdonik, and Moore as essential workers, which allowed them to work on campus. Verdonik operated the 3D printing of the headband and the support pieces that attach to the bottom of the shield for better structure, while Moore used the laser printers on Mountaintop Campus to cut the shields (from PET plastic), the neoprene comfort guard, and the neoprene strap. (Listen to episode 4 of the *Rossin Connection* podcast—*go.lehigh.edu/RossinConnection*—as Slocum's team takes you inside their labs to explain their production process.)

By early May, they had delivered more than 1200 shields to local hospitals and emergency management agencies. At

DISINFECTANT RESEARCH AIMS TO STICK IT TO CORONAVIRUS

AS THE PANDEMIC TOOK HOLD, disinfectants were wiped clear from store shelves, elevating common cleaning products to liquid gold status. Yet because these formulas rely primarily on alcohol (which evaporates quickly) to kill germs, their effectiveness is relatively short-lived.

An interdisciplinary team of researchers within Lehigh's Institute for Functional Materials and Devices (I-FMD) seeks to achieve longer-lasting disinfection results by developing a liquid polymer spray with a superior ability to cling to surfaces. The coating will "chemically functionalize" surfaces by disabling the outermost lipid or fatty envelope of the virus.

"Developing this virucidal technology to disrupt the indirect transmission of novel coronavirus and other diseases becomes increasingly more important as our communities move toward resuming normal activities and movements in public," says researcher and I-FMD director Himanshu Jain. "A functional material will be much more effective than having to rely on frequent cleanings with standard disinfectants in high-traffic areas, such as entrances to restaurants and restrooms."

The team also includes Frank Zhang (bioengineering/mechanical engineering and mechanics), Xuanhong Cheng (BioE/materials science and engineering), and a faculty member from the University of Cincinnati's College of Pharmacy. The group has expertise in virology, materials surface engineering, disinfection in health care, and virus detection. Industry partner Solvay USA will help develop the technology and manufacture new polymers. The project received support from Pennsylvania's Manufacturing PA Innovation Program COVID-19 Challenge.

that time, DuPont had donated a 1000-foot roll of PET plastic, enough for 1000 shields, and the team had set up a crowdfunding site to ensure they were able to continue meeting local needs. They hit the 5000 mark at the end of June, as mass manufacturing began to catch up with demand. "We were able to help fill the gap," says Slocum.

Nurses at Lehigh Valley Health Network are among the health care providers who have received face shields manufactured at Lehigh.

The team's ability to finalize a design so quickly was due in large part to their ability to leverage a variety of technologies—including 30 or so 3D printers that had been sitting idle with students no longer on campus—and get the best out of each.

"We know how to use these tools, and we're good at designing solutions," says Slocum. "So we have the capabilities from the physical resources, but also on the intellectual side."

Their efficient response also reflects the connections the university has with the community.

"We've spent a long time and a lot of institutional resources building relationships with our local hospitals," says Slocum. "Pretty much everybody I've dealt with both at St. Luke's and Lehigh Valley Health Network at some point has toured the additive lab, and I've talked to them about how additive manufacturing can be brought to bear on some of their health care needs. Leveraging those resources and relationships allows us to be proactive community partners."

Slocum, Verdonik, and Moore never anticipated becoming essential workers during a pandemic. But when the call from those in need came, there was never a question how they—or the university—would respond.

"People have been so appreciative," Slocum says. "And it just feels so good to do something where you're helping somebody stay safe during this chaotic time. That, to me, is the core of what we should be doing as humans, as engineers, as Lehigh practitioners. That's where we can make the greatest difference in the world." *—Christine Fennessy*

Understanding the mechanism of infection

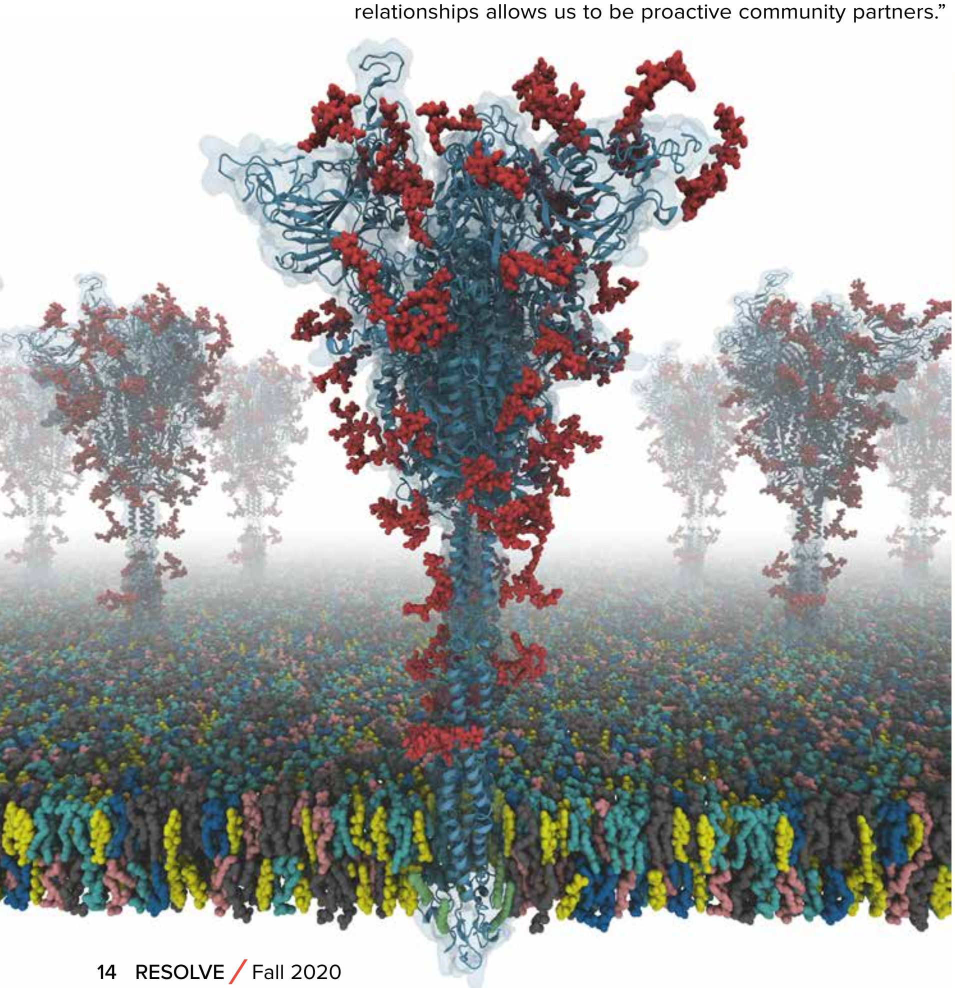
The world is anxiously awaiting a vaccine to curtail the spread of COVID-19 and bring the pandemic to an end.

By imitating a virus, a vaccine triggers the body's immune system to generate a series of responses, including the production of antibodies by B-lymphocytes. If the body is then exposed to the actual virus, these antibodies will recognize it and neutralize it.

But a vaccine may not be a panacea for this crisis.

"How long that immune response will last is a big question," says Frank Zhang, an associate professor of bioengineering and mechanical engineering and mechanics. "And the virus could mutate. Right now, the mutation rate for SARS-CoV-2 [the virus that causes COVID-19] is not that bad. But in a few years, it could mutate to the point where

TOP: COURTESY OF LEHIGH VALLEY HEALTH NETWORK; ILLUSTRATION: YEOLKYO CHOI



'COMPUTATIONAL MICROSCOPE' KICK-STARTS VACCINE RESEARCH

THE SPIKE PROTEIN (or S protein) of SARS-CoV-2 facilitates viral entry into host cells, which makes it a main target for vaccine and antiviral drug development.

Researchers from Lehigh, Seoul National University, and the University of Cambridge have collaborated to produce the first open-source all-atom models of a fully glycosylated full-length SARS-CoV-2 S protein. Scientists can use the models to conduct innovative simulation research for the prevention and treatment of COVID-19, according to Wonpil Im, Presidential Endowed Chair in Health, Science, and Engineering at Lehigh.

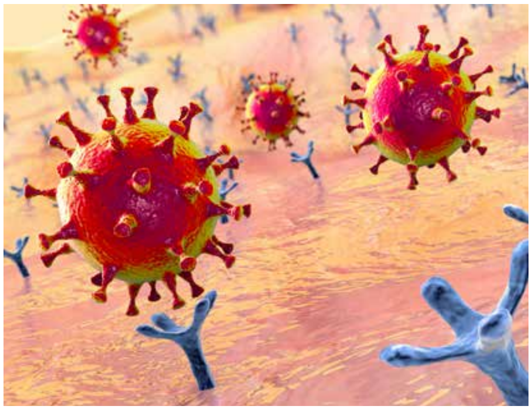
The team used a model-building program designed by Im called CHARMM-GUI. (GUI stands for "graphical user interface.") It simulates complex biomolecular systems simply, precisely, and quickly. Im describes the program as a "computational microscope" that enables scientists to understand molecular-level interactions that cannot be observed any other way.

"Our team worked day and night to create these models for the scientific community," says Im. "It was challenging because there were many regions where simple modeling failed to provide high-quality results."

the vaccine doesn't work anymore. Think about our experience with the flu vaccine. Every year, the CDC has to predict how the flu will mutate, and design the vaccine accordingly. Sometimes the vaccine works well, and sometimes it doesn't. So it's much better to have antiviral drugs that don't rely on a human immune response."

The development of such drugs is Zhang's ultimate goal. He and his team are using atomic force microscopy (AFM) and optical tweezers (a tightly focused laser beam that can isolate and move micron-scale objects) to study how a surface protein called a spike protein on the SARS-CoV-2 virus interacts with human cell surface receptors.

"One known receptor is the ACE-2 receptor, which is expressed in many cells, but specifically in epithelial cells in our upper and lower airway," says Zhang. "That's why when the coronavirus is inhaled, it attaches to those epithelial cells. The spike protein not only sticks to the ACE-2 receptor, but it also has some built-in activation and invasion steps that we still don't understand. But essentially, the virus finds a way to get into those epithelial cells and replicate itself, and that's how we get infected."



A conceptual illustration shows the SARS-CoV-2 virus binding to an ACE-2 receptor on a human cell.

If researchers better understood that three-step mechanism of infection (attachment, activation, and invasion), they could potentially develop antiviral strategies to block one or more of the steps and keep the virus from entering human cells in the first place.

To maximize their efficacy, however, Zhang says those antivirals should target well-conserved processes for viral entry, meaning those mechanisms that essentially don't change, no matter how much the virus itself mutates. For example, the attachment step is not well conserved: Currently, the virus attaches to the ACE-2 receptor. But it could mutate, and adhere to a different receptor. Conversely, the invasion step—when the virus essentially punches a hole in the human cell, inserts its genome, and starts replicating—is very well conserved, says Zhang.

"No matter how the virus mutates, that mechanism is not going to change much," he explains.

While significant research is being conducted on this invasion step, little is known about the activation step. By using AFM and the optical tweezers, and working in tandem with faculty members Wonpil Im, a molecular modeler, and Anand Jagota, an expert in biomechanics, Zhang is developing experimental techniques to understand how the spike protein changes shape and gets activated. *—CF*

PRODUCTIVITY, INTERRUPTED

FEELING EXASPERATED by the shift to remote work and school? Larry Snyder, a professor of industrial and systems engineering, and Suzanne Edwards, an associate professor of English in Lehigh's College of Arts and Sciences, can relate.

In "Yes, balancing work and parenting is impossible. Here's the data," an op-ed they composed for *The Washington Post*, the parents discuss how they've struggled to complete their work while homeschooling and caring for their children, ages 8 and 12.

"On most days, it feels as if we get a reasonable amount of time to devote to our professional tasks. And yet we are unable to concentrate enough to complete the work," they write.

Furthermore, "our personal responsibilities interrupt our professional ones, which interrupt our personal ones—and we feel we are failing at all our jobs."

To better understand their struggles with productivity, Snyder and Edwards conducted a micro-experiment, collecting and analyzing data to measure the interruptions they faced from their children within a three-hour period.

"Looked at one way, the situation appeared manageable: Over the course of three hours, the parent on duty was interrupted for a little over half an hour in total, meaning they got almost 2.5 hours of work time. But that time didn't come in two clean chunks: The parent was interrupted 45 times, an average of 15 times per hour. The average length of an uninterrupted stretch of work time was three minutes, 24 seconds. The longest uninterrupted period was 19 minutes, 35 seconds. The shortest was mere seconds," they explain.

In the piece, Edwards and Snyder also discuss policy solutions that could help parents.

THE AVERAGE **UNINTERRUPTED** STRETCH OF WORK TIME WAS **3 MINUTES, 24 SECONDS** OVER A 3-HOUR PERIOD

TOP: ISTOCK/EDIEBLOOM; ILLUSTRATION: KATERYNA KON/SHUTTERSTOCK

BY KELLY HOCHBEIN AND CHRISTINE FENNESSY

STUDYING RESILIENCE IN REAL TIME

Interdisciplinary team examining effects of perception on communities recovering from natural disasters shifts focus as the impact of the pandemic unfolds

OUR PERCEPTIONS can shape our reality. It's an idea that Paolo Bocchini finds fascinating, particularly when it comes to studying recovery after a natural disaster.

"If a hurricane destroys your factory, and you don't believe that utilities will be restored quickly enough in your neighborhood, you may decide against rebuilding your factory in the same spot," says Bocchini, an associate professor of civil and environmental engineering (CEE). "The same reasoning applies to infrastructure services. If the water department doesn't think power will be restored to a certain area, it may avoid servicing that area altogether. So the perception of recovery can impact the actual recovery. But sometimes, these perceptions are wrong."

Bocchini has long been using metrics of resilience to study and model the recovery of infrastructure systems after natural disasters like earthquakes and hurricanes. But he'd never considered the role of perception in regard to resilience and recovery within communities, nor how it could come into play if the disaster were a pandemic.

Bocchini is part of an interdisciplinary team within Lehigh's Institute for Cyber Physical Infrastructure and Energy (I-CPIE) studying just that. The team includes Rossin College professors Brian Davison (computer science and engineering) and Richard Sause (CEE) as well as faculty and other researchers in three other colleges at Lehigh.

"Our desire was to establish a group led by social scientists who study perception," says Bocchini. The initial plan was to investigate how perceptions of recovery among the general population compared with the actual recovery of communities in North Carolina that were hit by Hurricane Florence in 2018. But just before team members were set to travel to conduct interviews, COVID-19 upended the world.

"COVID made it impossible to do what we wanted to do about Hurricane Florence, but it gave us another disaster to study. In real time, we could observe the loss of functionality of many different systems, the perception around this loss, and the recovery," he says.

"WE HAVE QUANTITATIVE MEASURES OF RESILIENCE FOR SERVICES AFTER **NATURAL DISASTERS**. THE SAME CONCEPT COULD WORK FOR **PANDEMICS**."

—Paolo Bocchini

The team wrote up a new proposal and secured more funding. Now, they're conducting a longitudinal study of how people in the U.S. perceive, respond to, and recover from the impact of COVID-19. While the goal remains the same—to develop comprehensive, interdisciplinary ways to understand and assess community resilience—the unprecedented nature of the pandemic allows the team to examine not only how different groups perceive a pandemic but also how those perceptions influence behaviors and relate to resilience of critical sectors.

After developing surveys and interview questions, team members surveyed a sample of approximately 2,500 individuals in April and resampled them two weeks later, with short follow-ups continuing to take place every six to eight weeks. In-depth phone interviews with citizens and key decision-makers in Pennsylvania's Lehigh Valley, as well as in counties in New Jersey and California, are also providing data. Questions focus on participants' perceptions of their own resilience and mental health, the challenges they face, their infrastructure usage, and their perceptions of their state and local communities, including the perceived economic impact. The team will also collect objective data related to confirmed cases of COVID-19, mortality rates, infrastructure usage, economic activity, and other impacts.

The team plans to address sensemaking by examining the schemas (outlines for thinking about situations that guide a response) that individuals bring to this pandemic. Schemas are informed

ILLUSTRATION: ISTOCK/ARTQU

by previously experienced events, such as a hurricane, a terrorist attack, or other public health crisis. The team will also investigate the communities with which individuals identify—national, local, religious, occupational—that can guide behavior. Researchers will then assess participants' self-reported behavioral responses throughout the pandemic.

So far, the gathered data has been informative, particularly with regard to stress and anxiety, says Dominic Packer, a professor of psychology in Lehigh's College of Arts and Sciences. "People who've lost their job or have less income because of COVID are obviously more stressed out," he says. "Anyone who's experienced disruptions—like having trouble getting health care, or parents managing kids at home—has more elevated stress."

However, it seems that community identity can predict lower immediate stress or decreased stress over time.

"It's this feeling that you live in a community where you're connected to other people, that they're supportive, that your community is coping fairly well," he says. "That's a strong predictor of less stress. It's actually one of the strongest predictors we're seeing in our data. It makes sense because in a disaster, you suddenly are bound to your community. You can't really go anywhere else, all your outcomes are linked to factors like 'Do my grocery stores have toilet paper?' and 'Is my hospital able to function?'"

Early data also indicates that individuals who focus on the local community rather than issues at a state, national, or global level experience less stress. "That was true even in the hardest-hit states," says Packer, "I think because although things are terrible overall, in your local community, for most people…neighbors are helping each other."

Bocchini says the ultimate goal is to devise a way to measure what he calls the "lag" between perception and reality. In other words, to show the lag exists, and that it can be quantified.

Such understanding will enhance the models depicting community resilience after a disaster.

"Understanding this lag can make a difference when you're assessing decisions about how to allocate funding for a certain retrofit, what protocols should be prepared, or how many crews should be on standby in case of a coming hurricane. Or in this case, whether parents will send their kids back to college. All of these decisions rely on some predictive models, and the more accurate the predictive models are, the better these decisions will be," he says.

Bocchini is particularly excited to see if the paradigm he's used for more than a decade to assess recovery in infrastructure systems after a natural disaster can be applied to a range of negative events, from coral reef extinction to pandemics.

"We have standardized, quantitative measures of resilience for services after natural disasters," he says. "The same concept could work for pandemics."

Bocchini and his team are taking advantage of the unusual vantage point the virus has given them—an abundance of time to study its ripple effects on our critical services.

"If we have good models of the kinds of impacts made by a pandemic and the evolution of those impacts, it will allow decision-makers to invest in mitigation and preparedness. So if it happens again, we'll be more prepared to face it."

CLOCKWISE FROM TOP: ISTOCK/XAVIERARNAU; "ESSENTIAL THANKS" (CC BY-NC-ND 2.0) BY RUSS ALLISON LOAR; "COVID-19 CAUTIOUS SHOPPER" (CC BY-NC-ND 2.0) BY GILBERT MERCIER; ISTOCK/SDI PRODUCTIONS; ISTOCK/NYCSHOOTER

BY CHRISTINE FENNESSY

ARRIVED

Meet the 2020 Class of NSF CAREER Award recipients

ACROSS HIGHER EDUCATION, recognition from the National Science Foundation's Faculty Early Career Development Program is seen as validation that a newer science/engineering faculty member is growing into an academic powerhouse.

NSF CAREER grants support junior faculty members who exemplify the role of teacher-scholar through outstanding research, top-notch educational instruction, and the integration of the two pursuits. Each award provides stable support of approximately $500,000 over a five-year period.

In the Rossin College, 30 percent of active faculty have earned the NSF CAREER award since its inception. And since 2015, an astounding 16 of the college's professors—more than 75 percent of eligible new faculty over this period—have secured this prestigious funding.

Collectively, these accomplishments tell a powerful, interdisciplinary story about a scholarly community on the rise. One that identifies, nurtures, and celebrates research and educational innovators who are developing into the future leaders of their respective fields. The next chapter of that story begins here...

Lesley Chow

A BETTER WAY TO REBUILD CARTILAGE

If you're able to walk without pain, give a silent shout-out to your cartilage.

Every time you take a step, this flexible tissue absorbs the load and transfers it to the bone, allowing you to move freely. But unlike bone, if cartilage gets damaged—by injury, wear and tear, or inflammation—it can't regenerate. Over time, the damaged tissue degrades, and walking becomes progressively more painful.

"Eventually, you'll develop osteoarthritis, which affects about 32 million Americans," says Lesley Chow, Frank Hook Assistant Professor of Bioengineering and Materials Science and Engineering. "And while there are some surgical interventions, you eventually hit a point where you're in so much pain and have such a loss of mobility that you need a total knee replacement."

Effective interventions for osteoarthritis don't yet exist because cartilage is so difficult to regenerate.

But if a biomaterial could be developed that successfully directed regeneration of the entire osteochondral ("osteo" for bone, "chondral" for cartilage) tissue, says Chow, cartilage injuries could be treated earlier and degeneration could be slowed or halted altogether.

"If we can intervene when you first have that injury, this therapy has potential to buy you 10 or more years—or maybe you would never need a knee replacement," she says. "That's the dream."

It's a dream that's now a step closer: Chow's CAREER award will support her lab's work in refining their 3D-printed biomaterial to provide exact signals to cells to form tissues organized in the same way as native osteochondral tissue.

"We know that our bodies have cells that are capable of regrowing these tissues, but what if we aren't giving them the right chemical and

physical cues?" says Chow. "We would like to be able to change the chemistry of our biomaterial without changing the physical properties. This is very difficult because these properties are inherently tied to each other, but my lab has developed a platform where we can change these cues independently."

The team's 3D-printed scaffolds have yielded promising results. Prior to printing, peptides (short segments of proteins) are synthesized with sequences designed to promote bone or cartilage formation. The researchers attach these peptides to biodegradable polymers and 3D print the resulting peptide-polymer conjugates to fabricate a peptide-functionalized material.

"It's like a color printer," says Chow. "Say you want to print your bone-promoting scaffold first and then transition to one that promotes cartilage. You just switch the ink in your printer. So within the same print, you end up with both bone- and cartilage-promoting peptides in one continuous biomaterial."

With a better understanding of how cells respond to specific chemical and physical signals, the team hopes to fine-tune an "optimal material" that drives formation of the entire osteochondral tissue. Chow's ultimate goal, however, is twofold: a biodegradable implant and a fundamental tool set that can be translated to other tissues like tendon, ligament, and skin.

"We want this platform to be an enabling technology for other groups—researchers who want to better understand the properties they need to develop in their own materials to regenerate other tissues of interest."

WE WANT THIS PLATFORM TO BE AN **ENABLING TECHNOLOGY** FOR RESEARCHERS SEEKING TO **REGENERATE** OTHER TISSUES OF INTEREST.

—Lesley Chow

Ganesh Balasubramanian

PREDICTING SUCCESS

"The general paradigm in manufacturing has been build, test, repeat," says Ganesh Balasubramanian, a P.C. Rossin Assistant Professor of Mechanical Engineering and Mechanics. "We're adding a layer so that the process becomes predict, build, test, repeat. Before you actually build anything, you're predicting what-if conditions for the process based on data from simulations and experiments. You can then use that information to guide and streamline the manufacturing process."

Balasubramanian is building a predictive framework to manufacture multi-principal element alloys and engineer surfaces with their coatings. MPEAs are a new class of materials that are generally composed of five or more metals in equal proportions. Preliminary studies have demonstrated that MPEAs have superior mechanical strength and hardness, making them ideal as a protective coating on components like turbine blades, medical implants, ship surfaces, and aerospace parts.

"Those are all things that have to be strong and resist wear, corrosion, and extreme temperatures," he says. "Let's say a component on a space vehicle cracks or disintegrates under the thermal stress it experiences upon reentry. You could replace that material with something that could better withstand high temperatures, but then you'd be adding weight. Ideally, you want to add something to the surface of that component that protects it while retaining the properties of the material beneath it."

The effective processing of MPEAs, however, has been elusive.

Balasubramanian's CAREER award supports the collection of data—through computational predictions, quantification of uncertainties, and experimental characterization—that will help guide the additive manufacturing process of these alloys. Such information will essentially create a statistical record of what worked and what didn't in previous processing attempts. Researchers can then use those data points in a predictive way, incorporating them into their next round of processing, and ultimately move closer to successful repeatability in MPEA manufacturing.

This approach could accelerate the manufacturing process in fields such as propulsion, machinery, transportation, and medical devices by about 50 percent, he estimates, and reduce costs associated with the material and process design phase. His framework will also represent a step toward smart manufacturing, where artificial intelligence and supercomputing are built into the fabrication process.

"Data is constantly being generated by the things we do," Balasubramanian says. "We have a unique opportunity to take advantage of that and formalize the process of manufacturing."

Ethan Yang

EXPLORING THE IMPACT OF GREEN INFRASTRUCTURE ON URBAN FLOODING

"Rain gardens and rain barrels are considered green infrastructure because they're cost-effective, sustainable ways to keep heavy rainfall from flooding urban areas," says Y.C. "Ethan" Yang, an assistant professor of civil and environmental engineering.

However, when a city integrates these measures (which can be installed and maintained by homeowners) into their stormwater management plans, it's challenging to quantify their effects.

For one, Yang explains, municipalities can't test each rain garden—an area with native vegetation and porous soil that allows rainfall to slowly infiltrate—to determine how much water it absorbs. The same goes for measuring the capacity of individual rain barrels, collection units that connect to gutters and store water for later use on lawns and plants.

Hannah Dailey

AN INSIDE LOOK AT BONE HEALING

Broken bones have a unique capacity to heal. The new bone that forms along the fracture line, called callus, starts out as a soft tissue and, over time, it hardens into bone that is just as strong—or stronger—than before the break.

But in some cases, the healing process goes awry. This failure to heal is called a nonunion, a painful and often debilitating condition that requires further medical intervention.

"We know that nonunions happen in about 10 percent of fractures of the shinbone, and it's impossible to predict who will have one," says Hannah Dailey, an assistant professor of mechanical engineering and mechanics. "But patients who get a diagnosis of a nonunion can have higher rates of depression, opioid use, and addiction. They might be unable to return to work. So we want to be able to identify very early on when healing is not progressing well so surgeons can intervene sooner. The problem is that right now, you can't make that early determination."

IF WE CAN UNDERSTAND THE **MECHANICAL PROPERTIES** OF EARLY-STAGE TISSUE, WE CAN REFINE OUR MODELING AND **INTERVENE EARLIER.**

—Hannah Dailey

Dailey's CAREER award will support the further development of a virtual mechanical test that will make such a determination possible. This project will help to define the mechanical properties of new bone tissue as well as the overall structural behavior of healing bones.

Using specialized software on low-dose computed tomography (CT) scans of patients who have sustained tibial fractures, Dailey and her team build 3D mechanical structural models that identify regions of bone and callus. They run the models through finite element analysis software that divides the bone model into tiny zones that all have a mathematical relationship to each other. They then simulate different types of loads that mimic the conditions during healing. The technique is called virtual mechanical testing. The less the bone flexes under load, the more healed it is.

Using the same CT scans, they then

Yang seeks to form an academic-public-private partnership to create a collaborative learning environment for students from middle school to graduate school around sustainable stormwater management.

To be effective, gardens must also be kept free of debris and barrels need to be emptied. Often, cities don't have sufficient resources to ensure proper maintenance.

With his CAREER award, Yang is addressing these challenges right in Lehigh's backyard. Working with Bethlehem Township, he's developing a novel "human-cyberinfrastructure framework" that combines an Internet of Things–based green infrastructure network and agent-based modeling that incorporates stakeholder behaviors to advance the understanding of decentralized stormwater management.

In Yang's project, solar-powered sensors measure soil moisture beneath rain gardens and water level in rain barrels, sending real-time data to a web platform for officials to determine how well (or not) the infrastructure is functioning per its design criteria.

Property owners can use Google Home or Amazon Alexa (instead of completing the current legally required handwritten form) to record the timing and frequency of upkeep. By analyzing the data, Yang says, "maybe we can incentivize those who live in flood-prone areas to step up their maintenance."

Yang is also building a model that simulates the location of potential flood zones, as well as property owners' behavior. The model will quantify the effects on potential flood mitigation under various scenarios of green infrastructure installation, maintenance, and climate.

"Say a storm is coming," he says. "We'll run the model and identify which areas are most prone to flooding, and then the township can send out a warning to local communities along the lines of 'Hey, make sure your rain barrel is empty or your rain garden is clean.' Traditional modeling for stormwater management does not include this human element. By combining both the natural and human systems, we'll have a better understanding of how this decentralized system works as a whole."

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digitally re-create a healthy version of each person's leg and perform the same virtual mechanical tests. When they measure the flex of the unbroken leg against the fractured leg, the resulting percentage helps them determine how stiff the broken bone is compared with the healthy one. The stiffer a bone is early in the healing process, the quicker the patient can bear weight.

Preliminary results have found that the virtual mechanical test significantly correlates with how long it takes patients to heal, and could successfully identify a nonunion. It is the first such test of its kind to do so.

"If we can understand the mechanical properties of early-stage tissue, we can refine our mechanical modeling," says Dailey, "and intervene earlier to reduce the tremendous burden on these patients."

Dailey is partnering with the Perry Initiative, a nonprofit dedicated to inspiring women to enter the fields of orthopedic surgery and engineering, to create a hands-on learning module the organization can use during its outreach.

VIRTUAL REALITY

BY **CHRIS QUIRK**

With a successful pivot to remote internships, Lehigh@NasdaqCenter plugs aspiring engineers into the 'startup experience' of Silicon Valley and beyond

AMID THE TUMULT of the COVID spring, as Lehigh students, professors, and administrators adjusted to a new, socially distanced normal, Samantha Dewalt was warily eyeing the quickly approaching summer.

Dewalt is the managing director of Lehigh@NasdaqCenter, an academic in-residence collaboration with the Nasdaq Entrepreneurial Center. Launched in 2017, L@NC partners with Lehigh's Western Regional Office, located in the San Francisco Bay Area.

> "THESE STUDENTS BRING BOTH THE **BUSINESS** AND **TECHNICAL** MINDSETS TO THEIR WORK—AND THE COMBINATION IS POWERFUL."
>
> —Samantha Dewalt

Each year, L@NC offers two summer programs that sharpen students' entrepreneurial chops. Startup Academy (a tie-up with Lehigh Business) matches interns with small and mid-size Silicon Valley startups. The Global Entrepreneurial Fellowship (in conjunction with Lehigh's Baker Institute) places students in startups internationally. Both opportunities attract Rossin College students, many of whom are enrolled in interdisciplinary majors.

With the clock ticking, and COVID-19 cases proliferating, it seemed the pandemic would snuff out the summer opportunities for the 2020 cohort. But Dewalt and James Berneking, L@NC innovation programs manager, were not about to bail on their charges. They lit up their Silicon Valley and global networks, and scoured directories for small, innovative startup operations that could accommodate remote interns. Despite the time crunch—and thanks to some quick logistical footwork—Dewalt and Berneking were able to land virtual placements for the 26 students.

The interdisciplinary nature of Lehigh@NasdaqCenter internships make the experience particularly valuable for young engineers. "These students bring both the business and technical mindsets to their work—and the combination is powerful," says Dewalt. "Since the startups we team with are smaller, our students often work alongside the founders and leadership teams, so they have to grasp the business side. They might be thrown into projects using unfamiliar programming languages or tools they've never encountered. They're learning on the fly, and because of their engineering background, they are able to rise to the challenge."

Sheina Patel '21, a finance and industrial and systems engineering dual major, and Oliver Walsh '21, a computer science and business (CSB) major, found themselves working with Ecomedes, which offers software and technology that streamlines sustainable commercial building. Patel began conducting data analytics on target customers, analyzing platform usage, but was quickly moved into creating training videos for clients. She also took over social media duties. "I didn't have much experience with video editing, so I had to learn a lot of new skills quickly,"

Patel says. That included Photoshop, QuickTime, screen recording, and creating snappy scripts that delivered information concisely. "I got to apply a more creative side of myself."

CSB majors Dave Jha '22 and Peter Luba '22 interned at uGlobally, an international consulting firm. They were tasked with revamping the company's web presence. "The day we started, they asked us to fix a few things, and as we went through their website, we

L@NC interns, including Sheina Patel '21 (top right), splashed on the Nasdaq Tower in Times Square in celebration of this career path milestone.

TOP LEFT: CHRISTA NEU; TOP RIGHT: NASDAQ; BOTTOM: JOSH EDELSON PHOTOGRAPHY

realized it was kind of disorganized and had reliability issues," says Jha. "We asked if we could rethink their site and move it to a different platform."

Jha and Luba got the green light to overhaul the website. "Even though we're just a couple of young kids, they saw that we were methodical, and we identified a better solution that could address all their issues," Jha recalls. "It was daunting at first, but we were lucky that the founders trusted us. That's one of the beauties of entrepreneurship at these small startups—people are taking more risks." The revamped site went live in July and "everything you see was completely built by us," Jha says.

These experiences illustrate the advantage of teaming up with smaller startup operations, explains Dewalt. "Mid-stage startups are hungry for talent and offer a unique opportunity for students to work on real, useful projects, often tied to key company objectives." Because resources are at a premium in these smaller operations, students have to wear a lot of hats. "This is very different from a traditional internship, where you have a specific role. Students have to be creative, and there's a lot of dynamic ambiguity, so it develops their entrepreneurial mindset," says Dewalt. "This is the true startup experience."

It's a two-way street, according to Kathleen Egan '90, CEO of Ecomedes. "The interns bring a fresh view, and are able to contribute quickly," says Egan. "Startups can be daunting, but working on the inside gives interns insight into entrepreneurship. They're working on valuable projects, because that's the only kind of projects we have."

Working remotely rather than on-site in Silicon Valley did not dampen Patel's assessment of her summer. "I got a lot of good takeaways. I learned about myself and what I might want to do in the future," she says. "I've become more confident, and if someone says, 'Hey, I need you to get this done,' even if it's something I've never heard of, I'll figure it out."

With a similar can-do mentality, Dewalt and her team found inspiration in their successful recalibration of the center's offerings to rapidly launch a brand-new track for the 2020–21 academic year. "The Silicon Valley Innovation Internship" came directly out of the experience of going remote with the summer programs. The internship is a high-impact learning opportunity, with students engaging in a real-world internship remotely as they pursue their regular course of studies at Lehigh. "It's integrated into the curricular experience for students, and they're getting course credit for participating," Dewalt says. "We're also bringing in industry leaders, entrepreneurs, and investors from the innovation ecosystem here in Silicon Valley to connect with the students and deliver guest lectures. In addition, there will be personal and professional development components."

Another unanticipated upside of the summer's remote internships is that students got a taste of what's to come. "We're seeing more and more companies move to remote setups—especially some of the major tech firms," says Dewalt. "This is the future of work."

Palmieri's research interests include concurrency, data structures, transactional memory, synchronization, and distributed computing.

Getting in synch

Systems software researcher finds ways to make supercomputers even more super

Imagine a bank processing your withdrawals before it accepts prior deposits. Or an online store taking 500 orders for an item it has just 25 to sell. The chaos of overdrawn accounts and unfulfilled purchases would seem ridiculous. "Our minds work in a sequential way," says Roberto Palmieri, an assistant professor of computer science and engineering (CSE). "You'd say, 'Of course they'd process the deposit first.'"

Our expectation that computer systems conduct transactions in proper sequence and ensure that orders jive with inventory depends on a computer-science discipline known as synchronization, as well as distributed computing. Palmieri specializes in both. "The goal of synchronization is to make sure activities resulting from other activities are coordinated in a way that preserves data integrity and allows clients to observe events happening in the order they intended," he says. "But executing tasks one after the other doesn't work well in large systems where millions of people are doing the same thing at once."

With support from the National Science Foundation, Palmieri, along with associate professor Michael Spear and students in the Scalable Systems and Software (SSS) Research Group, have developed a method that makes synchronization in large-scale, high-performance supercomputers much more efficient—and as a result, substantially faster.

"OUR METHOD'S IMPACT IS NOT JUST IN **SOFTWARE DEVELOPMENT** BUT ALSO IN THE WAY DATA STRUCTURES ARE BEING TAUGHT **WORLDWIDE.**" —Roberto Palmieri

The innovation already has been incorporated into a widely used benchmark called Synchrobench. "Our method's impact is not just in software development but also in the way data structures are being taught worldwide," Palmieri says.

The value of teaching has been important to Palmieri since his own student days in Rome, where he studied computer science and began doing business in hardware, software, and systems services. "I wasn't thinking of getting a PhD or leaving Italy," he says. Then a teacher friend invited him to deliver a lecture on computer architecture. "I learned I loved to teach." Palmieri says. "The idea of helping someone through a hard problem and having them come out understanding a way to solve it—I thought that would be the most rewarding thing I could do."

After earning his master's and doctoral degrees, he was offered a position at Virginia Tech. His work attracted notice, and other schools came calling. "I decided to join Lehigh for two reasons: [CSE professors] Hank Korth and Mike Spear," Palmieri says. "To go where you can interact with people who know your language, understand where you're going, and have high standards made Lehigh a clear choice."

He's still guided by a vision of working with students to solve problems. The insight that led to faster supercomputers tackled a dilemma inherent in data structure. Unlike a typical laptop that contains four or eight processor cores in a single chip, a supercomputer uses hundreds of cores spread over several chips. Finding data across this vast archipelago of processors requires extensive searching in a process called non-uniform memory access (NUMA). A processor operating in a given NUMA zone is like an island, Palmieri says. If you stay on your own island, speed is high. But if you're figuratively on Samoa, it will take longer to execute a task if you first have to go to Tuvalu.

The SSS team exploited the home-island advantage by replicating key metadata that governs core memory across computing units. In effect, they put key data everywhere so processors didn't have to look for it beyond their own shores. At the same time, the team adopted an organizational strategy that tolerates small skews in metadata across the system. "You don't have to update the whole system right away if there's a modification in one island, which would destroy performance," Palmieri says. "The updates on other islands can happen later." Within the parameters of the 2018 paper, the system, called NUMASK, was shown to be two to 16 times faster than conventional systems.

"We're now applying knowledge and expertise from that project and taking it to the next level with more complex architecture," Palmieri says. One team, led by PhD student Jacob Nelson, is exploring a concept called bundling that helps better discern the path forward when traversing elements within a data structure without compromising speed or accuracy. Another team, led by PhD student dePaul Miller, is investigating use of the massively parallel processing capabilities of graphics processing units (GPUs) for new applications that share data.

Palmieri makes a point to encourage students to pursue their interests, not just his. "Branching out in new directions brings excitement and lets our scope as a research group grow."

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with agility and ingenuity
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ANSWERING THE CALL

With New Jersey under the strain of the rapidly spreading coronavirus, Dr. David Adinaro ’88 ’15 M.Eng. brought a systems engineering mindset to his role as chief medical officer of a field hospital caring for recovering COVID-19 patients.

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