THE JOHNS HOPKINS WHITING SCHOOL OF ENGINEERING MAGAZINE

JHU ENGINEERING

SPRING 2022

FROM THE DEAN

Dear WSE community,

AN ACADEMIC YEAR THAT STARTED WITH AN UNDERCURRENT OF UNCERTAINTY AND CAUTION HAS drawn to a close with the campus again bustling with activity. Spring Fair, commencement ceremonies on Homewood Field, and students hanging out on the "Beach" signal a return to normalcy that I think we all craved. I know I ended the year with a far deeper appreciation for both the routines of campus life and for the dedication and support our entire community provided over the last two years.

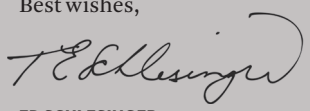
We have emerged from this challenging time in a position of terrific strength—one that provides many new opportunities for our faculty and students to explore new avenues for partnerships and collaborations across the university that will enable us to have an even greater impact on the world.

Just this spring, we launched SURPASS, a major new initiative with our colleagues at JHU's Applied Physics Laboratory, which builds upon more than half a century of collaboration that has yielded groundbreaking, life-improving innovation in areas ranging from space travel and medical robotics to materials. This work has defied expectations, time and again, and resulted in visionary solutions to critical challenges.

With SURPASS, we will foster new and deeper relationships and lower barriers to collaboration between our two organizations by supporting cross-divisional teams that will use multidisciplinary approaches to solve pressing societal problems. Our goal? To boldly reimagine what is possible. We expect to fund a small number of new projects each year at a significant level, with total support per year totaling at least $2.5 million.

Our ability to invest in new programs and promising areas of research, and the excellence of our academic offerings are to a great extent enabled through the support we receive from you, members of the Johns Hopkins Engineering community. Whether through philanthropy, providing internships for our students, or taking part in alumni events, your involvement makes a difference in the life of the school and in our ability to have an impact on the world, and I want to thank you for all that you do for Johns Hopkins Engineering.

Best wishes,



ED SCHLESINGER
Benjamin T. Rome Dean

CONTRIBUTORS

CATHERINE GRAHAM

LUNAR LANDINGS (P. 14)

Graham, communications associate for the Johns Hopkins Whiting School of Engineering, is a frequent contributor to *JHU Engineering* magazine. Since joining Johns Hopkins in 2017, Graham, who holds an MA in professional writing from Carnegie Mellon University, has covered research in artificial intelligence, cybersecurity, robotics, health care engineering, and COVID-19.

DAN PAGE

THWARTING CYBERATTACKS (P. 26)

Page, who works from his home studio in Cambridge, Ontario, is an award-winning illustrator whose work has appeared in publications across the globe, including *The Wall Street Journal, Rolling Stone, New Scientist,* and *The New York Times.*

ABOUT THIS MAGAZINE

Editor
Abby Lattes

Consulting Editor
Sue De Pasquale

Art Direction and Design
Cut Once, Inc. (cutoncedesign.com)

Associate Dean for External Relations
Megan Howie

Director of Communications
Abby Lattes

Director of Constituent Engagement
Kim Sheehan Dolan KSAS '13, MS '18

Contributing Writers:
Sarah Achenbach, Richard Byrne, Jamie Crow, Emily Gaines Buchler, Catherine Graham, Michael Eisenstein, Lisa Ercolano, Abby Lattes, Jason Lucas, Andrew Myers, Stephanie Shapiro, Danielle Underferth, Gina Wadas, and Amy Weldon

Contributing Photographers and Illustrators:
Michael Ciesielski, Will Kirk (A&S '99)/Homewood Photo, NASA, Dan Page, and Chris Vaccaro

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Abby Lattes: alattes@jhu.edu
Editor
Whiting School of Engineering

To update your mailing address or order additional copies, email engineering@jhu.edu or call 410-516-8723.

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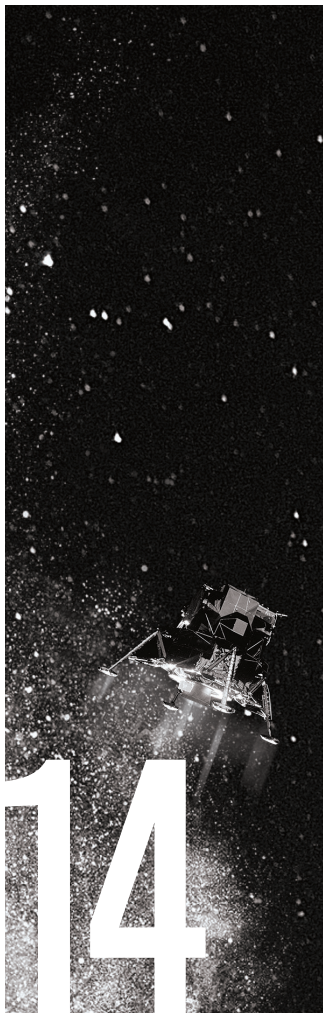
DEAN SCHLESINGER PHOTO: WILL KIRK/HOMEWOODPHOTO.JHU.EDU.

CONTENTS

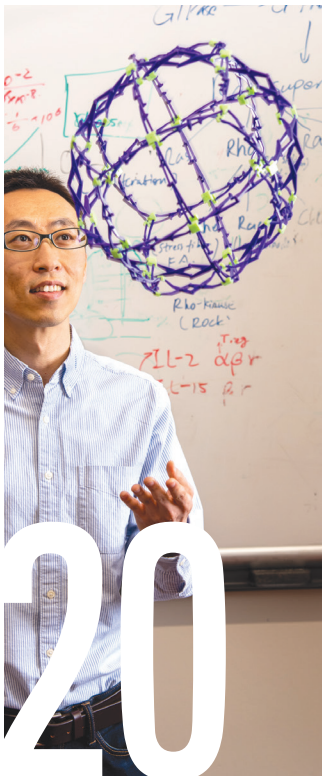


14

Lunar Landings

Jagged and sharp as broken glass, the debris churned up when a spacecraft descends can damage vital equipment. A student team is working to characterize those "plume surface" interactions to aid NASA's quest to push the boundaries of space exploration.

BY CATHERINE GRAHAM



20

Object Lessons

When it comes to everyday objects, engineers often have an uncommon fascination with the way things are designed and the reasons behind their utility. We polled a variety of our engineers and asked them to share their insights on a favorite object of their choosing.

COMPILED BY LISA ERCOLANO

26

Thwarting Cyberattacks

Threats to cybersecurity loom large today. Whiting School experts are focused on spotting cyber vulnerabilities and defending against them—a never-ending task, where the villains' tactics are evolving just as rapidly as the technology they exploit.

BY MICHAEL EISENSTEIN

9 GRADUATE PROGRAMS

428 DEGREES CONFERRED

2,261 GLOBAL ALUMNI

TO READ MORE GO TO:
EHE.JHU.EDU

A Department Makes Its Mark

FIVE YEARS AGO, THE WHITING SCHOOL OF ENGINEERING AND THE BLOOMBERG SCHOOL of Public Health joined forces to create the Department of Environmental Health and Engineering, a unique academic and research effort focused on environmental issues and their impact on public health.

Since its launch, the department has been the source of major breakthroughs in areas ranging from greenhouse gas emissions and water quality to improving how we measure health risks on a global scale, attracting top faculty members and students who are drawn to the department's unique structure, focus, and track record of making meaningful impact.

"Our department is unique and still evolving, and the opportunities it affords are fantastic," says Marsha Wills-Karp, the department chair and the Anna M. Baetjer Professor in Environmental Health. "Combining the skills and perspectives of environmental engineers and public health investigators under one roof has enabled us to pursue wholly new areas of research, develop new academic programs, and positions us, like no other institution in the country, to tackle today's and tomorrow's most complex global environmental challenges."

Recognizing the tremendous potential this new partnership held to advance knowledge, solve real-world problems, and provide unique educational opportunities, when the department launched, alumni Chaomei Chen, MS '88, and her husband, Yu Wu, MS '89, PhD '88, made a generous gift to support cross-disciplinary research projects and academic initiatives at the intersection of engineering and public health.

Over the past five years, the Chen-Wu gift has supported new research modeling the relationship between Parkinson's disease and manganese-contaminated water sediment, and one examining the links between fecal contamination and antibiotic resistance in the Chesapeake Bay. It also helped launch the Exposome Collaborative, a wide-reaching effort to understand the imprint of environmental influences and associated biological responses throughout the human life span, including a study focused on the exposome and childhood asthma in Baltimore City.

— ABBY LATTES

OPPOSITE PAGE: MICHIGAN STATE UNIVERSITY.

"We are inspired by Dr. Pierre's lifetime of tenacity, energy, vision, and leadership in ensuring opportunities for underrepresented students in engineering."

— ED SCHLESINGER

New Fellowships Honor a Pathbreaker

PERCY PIERRE, PHD '67, WAS THE NATION'S FIRST AFRICAN AMERICAN TO EARN A DOCTORATE IN electrical engineering.

He became the first African American appointed as both assistant secretary of the U.S. Army for research and development and the acting secretary of the Army, and was elected to the National Academy of Engineering in 2009. He is now an adjunct professor and Glenn L. Martin Endowed Professor at the University of Maryland's A. James Clark School of Engineering.

To honor his legacy, the Whiting School has established the Percy Pierre Doctoral Fellowships, which recognize outstanding incoming graduate students from underrepresented backgrounds. The fellowships provide recipients with monthly stipends, tuition, health insurance, and fees for their first two years of graduate school, as well as access to a variety of skilled mentorships and advising programs, and the chance to rotate through laboratories and mentors before finding the best fit.

"We are inspired by Dr. Pierre's lifetime of tenacity, energy, vision, and leadership in ensuring opportunities for underrepresented students in engineering," says Ed Schlesinger, Benjamin T. Rome Dean of the Whiting School. "We know that discovery, creativity, and innovation flourish in environments where individuals of different cultures and backgrounds can collaborate freely to solve problems in entirely new ways."

"Dr. Pierre created the model for mentoring under-represented minority students in his work with the National Academy of Engineering, Howard University, and Michigan State University. We wanted to ensure that our fellowships embodied his approach to cultivating and nurturing top talent," says Darlene Saporu, assistant dean for diversity and inclusion at the Whiting School.

Community building, networking, and career and leadership training are also key fellowship components.

"The overarching goal here is to help us build and support a critical mass of outstanding students from underrepresented backgrounds who can use their talents and gifts to make rich contributions to the field of engineering," Saporu says. "In this way, we are doing our part to carry on in Dr. Pierre's tradition."

— LISA ERCOLANO

AWARDS AND HONORS

Five members of the Whiting School's faculty recently received National Science Foundation CAREER Awards, which recognize early-stage scholars with high levels of promise and excellence. They include:

JEREMY BROWN, John C. Malone Assistant Professor, Mechanical Engineering, project: "Improving prosthesis usability through enhanced touch feedback and intelligent control"

NICHOLAS DURR, assistant professor, Biomedical Engineering, project: "Computational structured light imaging for widefield mapping of histologic primitives"

CHIEN-MING HUANG, John C. Malone Assistant Professor, Computer Science, project: "End-user robot programming by multi-modal instruction"

AXEL KRIEGER, assistant professor, Mechanical Engineering, project: "Advancing autonomy for soft tissue robotic surgery and interventions"

JAMIE SPANGLER, William R. Brody Faculty Scholar, assistant professor, Biomedical Engineering and Chemical and Biomolecular Engineering, project: "Engineered multi-specific antibodies to interrogate and manipulate immune checkpoint protein trafficking"

In addition, **JORDAN GREEN**, professor of biomedical engineering, was elected to the National Academy of Inventors. Green works within the chemistry/biology/engineering interface to answer fundamental scientific questions and to create innovative technologies and therapeutics to benefit human health.

A New Major and New Minor Make Their Debut

VENTURING BEYOND THE CONFINES OF TRADITIONAL ENGINEERING COURSEWORK, THE WHITING SCHOOL'S NEW BACHELOR OF SCIENCE degree program in Systems Engineering, offered through the Department of Civil and Systems Engineering, is trans-disciplinary and collaborative, connecting mathematics, engineering, social and physical sciences, and medicine. The major is designed to prepare students for a broad range of careers, including those related to energy infrastructure, smart cities, decision making in health care, data mining, and the cybersecurity of infrastructure.

The new minor in Energy focuses on technical aspects of sustainable energy and is offered jointly through the Krieger School of Arts and Sciences and the Whiting School of Engineering, drawing upon a variety of resources and co-curricular opportunities, including those made possible through the Ralph O'Connor Sustainable Energy Institute. It is designed to prepare students for careers in the public, private, and nonprofit sectors in areas related to the development, delivery, and management of energy for human use.

LIFELONG LEARNING FOR ENGINEERS

Early-career engineers and seasoned professionals wishing to remain at the cutting edge of their professions can now enroll in executive education programs and workshops offered through Johns Hopkins Engineering's newly launched Lifelong Learning initiative. Fourteen programs are now being offered, with additional courses in the works (see p. 25 for more information).

The programs, which span topics ranging from Healthcare Systems Engineering and Thinking and AI for Defense Industry to Blockchain Design and Implementation, are offered both online and in person in a variety of locations with continuing education credit. Learn more at lifelonglearning.jhu.edu.

Collaborating with Amazon for Life-Changing Solutions

AMAZON AND JOHNS HOPKINS UNIVERSITY ARE TEAMING UP TO harness the power of artificial intelligence. The new JHU + Amazon Initiative for Interactive AI, housed in the Whiting School of Engineering and involving multiple Whiting School-based research centers and institutes, will leverage Johns Hopkins' world-class expertise in interactive AI to build groundbreaking technologies in machine learning, computer vision, natural language understanding, and speech processing.

Sanjeev Khudanpur, an expert in these areas and associate professor of electrical and computer engineering, will serve as the initiative's founding director. "Hopkins is already renowned for its pioneering work in these areas of AI, and working with Amazon researchers will accelerate the timetable for the next big strides. I often compare humans and AI to Luke Skywalker and R2-D2 in *Star Wars*: They're able to accomplish amazing feats in a tiny X-wing fighter because they interact effectively to align their complementary strengths," Khudanpur says.

Ed Schlesinger, Benjamin T. Rome Dean of the Whiting School of Engineering, says: "We are very excited to work with Amazon. We value the challenges they bring to us and the life-changing potential of the solutions we will create together."

Prem Natarajan, Amazon's Alexa AI vice president of natural language understanding, says the partnership underscores Amazon's commitment to addressing the greatest challenges in AI. "This initiative brings together the top talent at Amazon and Johns Hopkins. These advances will power the next generation of interactive AI experiences across a wide variety of domains—from home productivity to entertainment to health."

— LE

Designing Sustainable Plastics

RECYCLING PLASTIC PRODUCTS IS A CHALLENGE. NOT ONLY ARE A LIMITED number of types of plastic recyclable, but because the recycling process also breaks down polymer chains and degrades the materials' quality, many can only be recycled a few times. As a result, recycled plastics tend to be suitable for use only in low-value products, such as single-use grocery bags.

A new type of plastic could change that. A team led by Whiting School engineer Thao "Vicky" Nguyen, a professor in the Department of Mechanical Engineering and a member of both the Hopkins Extreme Materials Institute and the Institute for NanoBioTechnology, is developing an approach that promises to turn difficult-to-recycle plastics into a tougher material suitable for use in high-performance and high-value products. The work is funded through a four-year, $1.8 million grant that is part of the National Science Foundation's Designing Materials to Revolutionize and Engineer our Future program.

"Our goal is to yield a plastic material that is stronger and tougher than conventional recycled plastics and that can have the same consistent properties as traditional plastics," says Nguyen. "We are hopeful that creating sustainable plastics will reduce the environmental impact of plastics production."

The team will produce the material by melting and blending two common but difficult-to-recycle plastic polymers: polyethylene and isotactic polypropylene. The researchers are developing a computational, data-driven methodology called Materials Architected by Adaptive Processing, or MAAP, to design the microstructure of the blend and control its processing, ensuring the production of high-value plastics with consistent strength and toughness properties.

The researchers note that their approach considers the variability of recycled plastic materials. For example, if plastic pellets from a recycling plant have significant impurities, the resulting polymer melt will be thinner. Their method should be able to adjust the temperature and pressure conditions of the processing line to produce a consistent blend.

Such an innovation will give plastics a second life; the recycled plastic created by MAAP will be exceptionally durable, meaning the material can be used in everything from appliances and construction products to personal protective equipment, like body armor, adds Nguyen.

The team hopes MAAP will allow other researchers to turn recycled materials into plastic polymer blends with superior properties.

"One of the broader goals for the project is to develop a database to make materials data more accessible for everyone," says Nguyen.

— CATHERINE GRAHAM

Thao "Vicky" Nguyen

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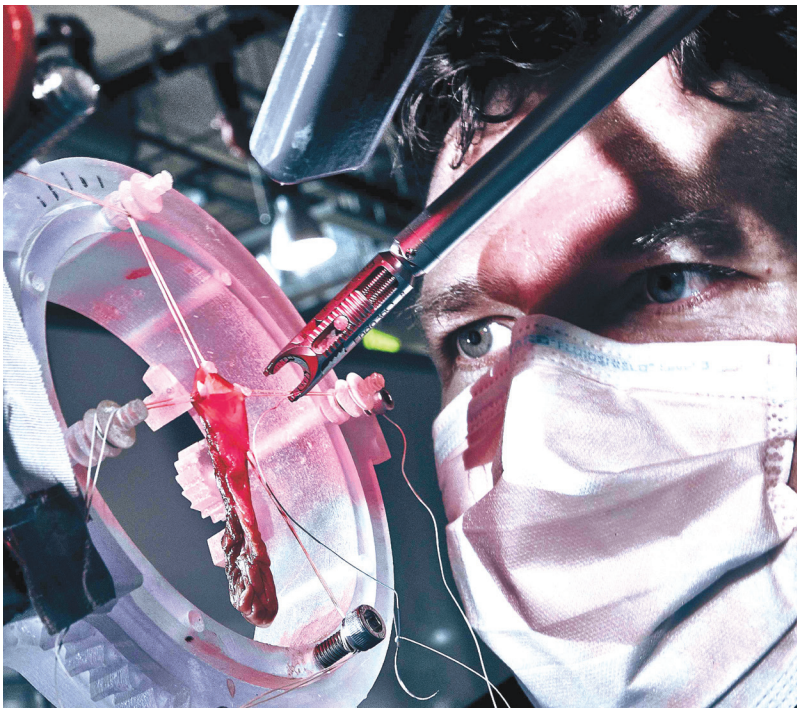


Axel Krieger

STAR of the Show in Laparoscopic Surgery

A ROBOT DESIGNED BY A JOHNS HOPKINS TEAM HAS PERFORMED LAPAROSCOPIC SURGERY ON THE SOFT tissue of a pig without the guiding hand of a human—a significant step toward fully automated surgery on humans. The researchers described the Smart Tissue Autonomous Robot, or STAR, recently in *Science Robotics*.

"Our findings show that we can automate one of the most intricate and delicate tasks in surgery: the reconnection of two ends of an intestine," says senior author Axel Krieger, PhD '08, an assistant professor of mechanical engineering at the Whiting School and a member of the Laboratory for Computational Sensing and Robotics. "The STAR performed the procedure in four animals, and it produced significantly better results than humans performing the same procedure."

The robot excelled at intestinal anastomosis, a procedure that requires a high level of repetitive motion and precision. Connecting two ends of an intestine is arguably the most challenging step in gastrointestinal surgery, requiring a surgeon to suture with high accuracy and consistency. Even the slightest hand tremor or misplaced stitch can result in a leak that could have catastrophic complications for the patient.

Working with collaborators at Children's National Hospital in Washington, D.C., and Jin Kang, the Jacob Suter Jammer Professor of Electrical Engineering, Krieger helped create the robot, a vision-guided system designed specifically to suture soft tissue. Their current iteration advances a 2016 model that repaired a pig's intestines accurately but required a large incision to access the intestine and more guidance from humans.

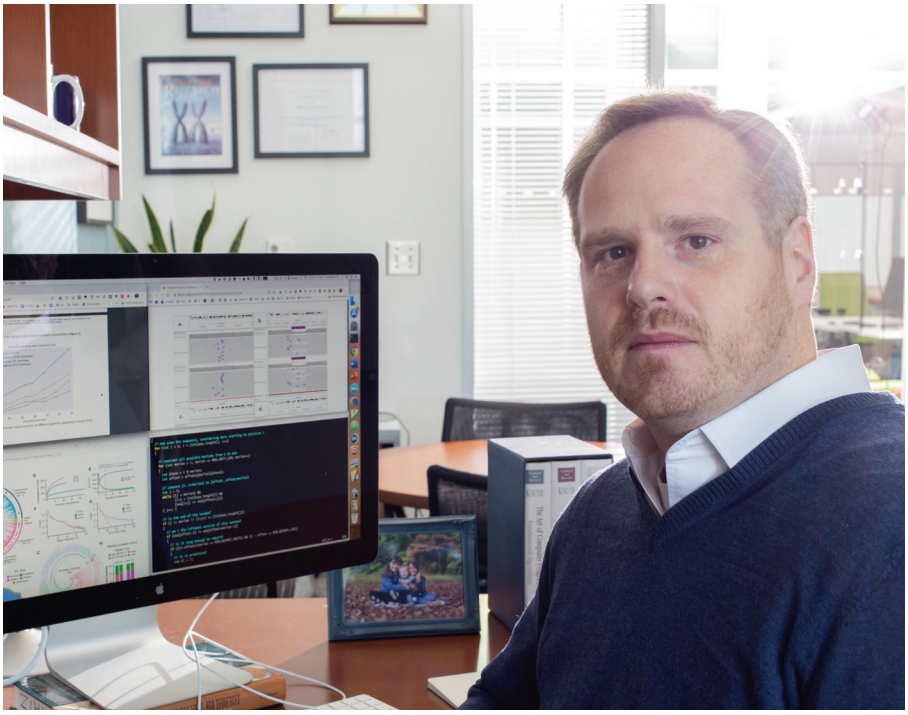
The team equipped the STAR with new features for enhanced autonomy and improved surgical precision, including specialized suturing tools and state-of-the-art imaging systems that provide more accurate visualizations of the surgical field.

Soft tissue surgery is especially hard for robots because of its unpredictability, forcing them to be able to adapt quickly to handle unexpected obstacles, Krieger says. The STAR has a novel control system that can adjust the surgical plan in real time, just as a human surgeon would.

"What makes the STAR special is that it is the first robotic system to plan, adapt, and execute a surgical plan in soft tissue with minimal human intervention," says first author Hamed Saeidi, a visiting research scientist in mechanical engineering.

What guides STAR is a structural, light–based, three-dimensional endoscope and machine learning–based tracking algorithm developed by Kang and his students.

— CG



"AnVIL is inverting the model of genomics data sharing, offering unprecedented new opportunities for science by connecting researchers and datasets in new ways and promising to enable exciting new discoveries."

— MICHAEL SCHATZ

Inverting the Model of Genomics Data Sharing

HARNESSING THE POWER OF GENOMICS TO FIND RISK FACTORS FOR MAJOR diseases relies on the costly and time-consuming ability to analyze huge numbers of genomes. A team co-led by a Whiting School computer scientist has leveled the playing field by creating a cloud-based platform that grants researchers easy access to one of the world's largest genomics databases.

Known as AnVIL (Genomic Data Science Analysis, Visualization, and Informatics Lab-space), the new platform gives any researcher with an internet connection access to thousands of analysis tools, patient records, and more than 300,000 genomes. The work, a project of the National Human Genome Institute, appeared in *Cell Genomics*.

"AnVIL is inverting the model of genomics data sharing, offering unprecedented new opportunities for science by connecting researchers and datasets in new ways and promising to enable exciting new discoveries," says project co-leader Michael Schatz, Bloomberg Distinguished Professor of Computational Biology and Oncology at Johns Hopkins.

Typically, genomic analysis starts with researchers downloading massive amounts of data from centralized warehouses to their own data centers, a process that not only is time-consuming, inefficient, and expensive, but also makes collaborating with researchers at other institutions difficult. Genetic risk factors for ailments such as cancer or cardiovascular disease are often very subtle, so researchers must analyze thousands of patients' genomes to discover new associations. The raw data for a single human genome comprises about 40 gigabytes, so downloading thousands of genomes to conduct such research can take several days to several weeks.

"AnVIL will be transformative for institutions of all sizes, especially smaller institutions that don't have the resources to build their own data centers," Schatz says.

In addition, studies requiring the integration of data collected at multiple institutions means each institution must download its own copy while ensuring that patient data security is maintained. This challenge is expected to become even greater in the future, as researchers embark on ever-larger studies requiring the analysis of hundreds of thousands to millions of genomes at once.

"Connecting to AnVIL remotely eliminates the need for these massive downloads and saves on the overhead," Schatz says. "Instead of painfully moving data to researchers, we allow researchers to effortlessly move to the data in the cloud. It also makes sharing datasets much easier so that data can be connected in new ways to find new associations, and it simplifies a lot of computing issues, like providing strong encryption and privacy for patient datasets."

— LISA ERCOLANO

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Finding the Story in the Emails

OFFICE-BASED EMPLOYEES SCRAMBLED TO ADAPT TO REMOTE WORK DURING THE COVID-19 PANDEMIC. Anecdotally, they were successful. But just *how* did they do it?

Check the emails. Microsoft recently gave researchers access to more than 360 billion work-related Outlook email exchanges. These communications from 1.4 billion accounts at 4,361 companies came without content—but with useful information about their frequency and pattern.

That's a lot of emails. And Carey Priebe, professor of applied mathematics and statistics at the Whiting School of Engineering, helped find the story in them. His work attacking real-world problems ranging from biomedicine to sex trafficking uses statistics and graph theory to unlock how complex networks function.

Scholars often have questions for which data can't supply the answers. "I take that as the 'nattering nabobs of negativism,'" says Priebe. "I turn it around: Can we say something useful with the data that we have, even though we can't answer your question?"

The analysis performed by Priebe and other researchers required 55,000 computer hours and offered a new window into changes in work behaviors driven by a global pandemic. In a working paper published in *Stat.ML* in September 2021, the authors observed that already existing silos in the workplace (and communications within them) intensified as employees worked remotely. Communications within those groups also deepened as a result. The researchers also found that while email did not replace the "serendipitous, in-person interactions" of pre-pandemic office life, the silos created in lockdowns were more "dynamic"—with memberships within them becoming less rigid as employees worked remotely.

"The increased siloing we observe need not be feared," they concluded.

Existing relationships with his former Johns Hopkins student and longtime collaborator Christopher White, PhD '09, who is the managing director for special projects with Microsoft Research, and with Jonathan Larson, principal data architect at the company, brought Priebe to the project.

"I'm their chief academic egghead when it comes to anything related to statistics on graphs," he says. Priebe adds that he is eager to bring more powerful quantitative resources to bear on the email data, fashioning "hypothesis tests" from the paper's larger conclusions to better interrogate and refine them.

"People identify with how things changed when the lockdown happened," Priebe observes. "So I found that gratifying—and a little bit surprising and very instructive."

— RICHARD BYRNE

Poor Air Quality in Fairbanks

IN FAIRBANKS, ALASKA, AIR POLLUTION LEVELS ARE UNUSUALLY HIGH WHERE AIR QUALITY LEVELS ARE DRIVEN BY BITTER TEMPERATURES AND pollutants. A multidisciplinary team of engineers and scientists has embarked on a research mission to understand why.

The Alaskan Layered Pollution and Chemical Analysis project involves more than 40 researchers from more than 15 national and international universities working with the University of Alaska Fairbanks to investigate the types of pollutants in the air, their impact on air quality, and what causes the pollutants to be trapped in the Arctic atmosphere. The seven-week study is funded by the National Science Foundation, the National Oceanic and Atmospheric Administration, and other international funding agencies.

Peter DeCarlo, associate professor of environmental health and engineering, is part of a Johns Hopkins-based team participating in the study.

When sunlight heats the Earth's surface-level air, pollution in the atmosphere is normally diluted by natural convection and air movement. That mixed air rises to a level in the atmosphere called the boundary layer. In areas outside of the Arctic, that boundary level can be a few thousand feet or higher, but in Fairbanks, located in a river valley without much wind, the boundary layer is much closer to the ground.

Ellis Robinson, a postdoctoral researcher in DeCarlo's lab who participated in the Fairbanks study, says these conditions result in "pooled stagnant air" around the city.

DeCarlo's team used an aerosol mass spectrometer to measure and identify the minute-by-minute chemical composition of atmospheric particles, offering powerful insights into daily air quality levels.

As most residents of Fairbanks spend the majority of their time indoors, understanding the relationship between indoor and outdoor air quality is important. When it's -30 degrees Fahrenheit outside and 65 degrees inside, that stark difference can change the composition of indoor and outdoor spaces, DeCarlo says. The team is studying what happens when outdoor air—including pollution particles and gases—gets inside and how regular indoor activities—such as cooking and running a pellet stove—can increase emissions in outdoor air quality.

The study will be used to improve the characterization of air pollution in Fairbanks and will potentially help to regulate future emissions in the area. While Fairbanks is an interesting case study, the results can apply to other Arctic areas.

"A lot of the manifestations of climate change are happening at an accelerated rate in Arctic areas," DeCarlo says. "Understanding the situation now allows us to see what might be happening in the future and try to prepare for some of those changes."

— JAMIE CROW

3 Questions

Interview by Lisa Ercolano

On the job, physicists who identify as LGBTQ+ experience—and also witness—behaviors ranging from shunning and homophobia to harassment at alarmingly high rates, according to the first-ever study of the experiences of LGBTQ+ scientists in a peer-reviewed journal. The study, which recently appeared in *Physical Review Physics Education Research*, also found that LGBTQ+ people from marginalized gender, racial, and ethnic groups faced even more challenges. Michael Falk, professor of materials science and engineering and vice dean for undergraduate education, was a co-author on that study.

1 Why is this study important?

We don't elicit the best science, engineering, art, or anything from our collective efforts if we exclude people from contributing based on arbitrary prejudices. We need every human being to be able to bring their "A game" to the work. It is hard to do that if you are facing active hostility or a basic lack of respect.

2 Did anything about the results surprise you?

Yes, one thing is how gendered the climate issues are for LGBTQ+ people in physics. Bisexual and lesbian women face significantly more hostility than gay and bisexual men, and gender-nonconforming people report the least welcoming environments. Trans people face the most discrimination. The second surprising finding was that observing exclusionary behavior, even more so than experiencing such exclusion, correlated with leaving the profession. It was sobering to realize that the public performance of exclusion was so impactful. That is a powerful insight, and a deeper understanding of how that plays out could benefit our inclusion efforts.

3 Does this study shed light on the experiences of LGBTQ+ engineers in general?

While each community is necessarily different, I believe that similar dynamics are in play in a variety of STEM disciplines. At the same time, there are different values in each community. It has been observed that the physics community tends to fetishize "genius" and "innate talent" in ways that may serve to reinforce assumptions and reward privilege. Engineering has a culture that strongly values professionalism and teamwork. These can be deployed to exclude people who don't immediately mesh with the team. Conversely, they can provide the impetus for more inclusive practices. But this will only be the case if we train our engineering students and instill in our colleagues an expectation that it is the height of professionalism to create teams that are open to diversity.

TECH TOOLS

Easier on the Head—and the Environment

Johns Hopkins engineers have created a shock-absorbing material that is light and reusable—and potentially a game changer in the manufacturing of helmets, body armor, and automobile and aerospace parts.

"The new foamlike material not only offers enhanced protection from a wide range of impacts but, because it is lighter than metal, could also reduce fuel consumption and the environmental impact of vehicles," says Sung Hoon Kang, an assistant professor of mechanical engineering and member of both the Hopkins Extreme Materials Institute and the Institute for NanoBioTechnology. "Also, we believe it will make protective gear more comfortable."

The team knew that the materials used to make current car bumpers and helmet padding don't perform well at high-speed impacts and often aren't reusable. They increased the materials' ability to withstand impact through the synergistic use of a foamlike geometry with high energy-absorbing liquid crystal elastomers, often found in actuators for soft robotics.

Kang and his team are now exploring a collaboration with a helmet company to design, fabricate, and test next-generation helmets for athletes and the military. The results appeared recently in *Advanced Materials*.

— JASON LUCAS

“The first thing we’re thinking of is testing at airports and stadiums.”

4/13/22

Ishan Barman, Mechanical Engineering, in *Fast Company*, on potential uses for a new platform for rapid, accurate COVID-19 testing, smaller than a postage stamp, that he and his team developed.

“It can discharge, components malfunction, and there are studies showing it increases mortality. It’s like a horse kicking you in the chest—it’s that painful.”

4/14/22

Natalia Trayanova, Biomedical Engineering, in *Fast Company*, on risks associated with defibrillators. The AI tool she and her team developed can predict an individual’s risk for sudden cardiac death and can help reduce the number of patients who receive the devices needlessly.

“Misinformation has always been present, even at higher proportions, before COVID-19 started. Many people knew this, which makes the ensuing misinformation spread during COVID-19 entirely predictable.”

1/12/2022

Mark Dredze, Computer Science, in *The Hill*, on the ubiquity of misinformation even before the COVID-19 pandemic.

“The problem is that e-cigarette aerosols contain other completely uncharacterized chemicals that might have health risks that we don’t yet know about.”

10/14/21

Carsten Prasse, Environmental Health and Engineering, in *Smithsonian Magazine*, on his study that found that electronic cigarettes contain nearly 2,000 chemicals—some of them potentially harmful.

LUNAR LANDINGS

Don't let the term "moon dust" fool you. Jagged and sharp as broken glass, the debris churned up when a spacecraft descends can damage vital equipment. A student team is working to characterize those "plume surface" interactions to aid NASA's quest in pushing the boundaries of space exploration.

*By **Catherine Graham***
*Photos by **NASA and Will Kirk***

For the first time this century, NASA plans to send humans to the moon, perhaps as soon as 2025. Humans haven't landed there since the last Apollo mission in 1972. The plan this time is to stick around. The agency wants to establish a permanent lunar base to serve as the staging ground for the next era of space exploration: sending the first astronauts to Mars.

PHOTO: WILL KIRK/HOMEWOODPHOTO.JHU.EDU

GRADUATE STUDENTS JUAN SEBASTIAN RUBIO, MIGUEL X. DIAZ-LOPEZ, AND MATT GORMAN

From its gargantuan craters to its ancient volcanoes, the moon is a scientific treasure trove that can tell us more about Earth and the solar system. Samples collected during the Apollo missions have helped scientists learn a great deal in the decades since.

But building a long-term presence on the moon presents a daunting range of technological and safety obstacles. NASA has enlisted a team of experts to work on a slew of research problems related to the mission, dubbed the Artemis program. Part of that team includes mechanical engineering graduate students Juan Sebastian Rubio, Miguel X. Diaz-Lopez, and Matt Gorman. The trio ran a series of experiments to understand plume surface interactions—or what will happen when a landing spacecraft approaches the lunar surface.

As more permanent bases are installed on the moon, sustaining life there will require more people, more supplies, and larger payloads. That means NASA will be sending landers that are 10 times heavier—and more powerful—than those sent 50 years ago, says Rubio, a NASA Space Technology Graduate Research Fellow.

"What we don't know is how that will affect the lunar surface. What happens to the soil below the spacecraft as it lands? Where are the displaced particles going, and how fast?" he says. "Currently, there isn't a lot of modeling that can fully predict the effects. We want to understand the physics behind this so we can predict future landings with more certainty."

As a spacecraft lands, engine exhaust plumes erode the lunar surface, kicking up dust, rock, and soil. Erosion can lead to deep craters under the lander, causing it to become unstable and topple over. And don't let the term "moon dust" fool you: This substance is as jagged and sharp as broken glass, and more than capable of damaging spacecraft and equipment.

"Mitigating landing risks is critical if we want to make routine trips to the moon. Even a relatively small thrust can send dust and rock particles flying at terminal velocity. If those hit nearby structures, we could be destroying the base every time we resupply," says Gorman.

Of course, the moon has only one-sixth of Earth's gravity and no atmosphere, making the lunar surface a perpetual

PHOTO: © NASA

PHOTO: WILL KIRK/HOMEWOODPHOTO.JHU.EDU.

vacuum. So observing plume surface interaction as it would occur on the moon requires an experimental setup mimicking those atmospheric conditions.

In summer 2021, the team headed to the NASA Marshall Space Flight Center in Huntsville, Alabama, and set up in the center's 15-foot vacuum chamber, modified to study surface erosion under near-lunar and Martian conditions.

"There are only a few chambers of this kind in the world. The fact that we were able to get in there and run our own experiments was incredible," says Gorman.

The team spent nearly two months devising a synchronized six-camera diagnostic system to study erosion caused by a gas nozzle running above a bed of simulated lunar soil. Using this setup, they captured crater formation and tracked the trajectory and velocity of the small soil particles. With this information, the team developed a model to predict cratering under any atmospheric conditions, a significant contribution to understanding plume surface interaction in space.

"The whole point is to understand the interaction between the lander's retropropulsive exhaust and the surface of the moon. No one has data like this, and it's highly valuable for SpaceX and Blue Origin, who will design the next generation of lunar landers," says Diaz-Lopez.

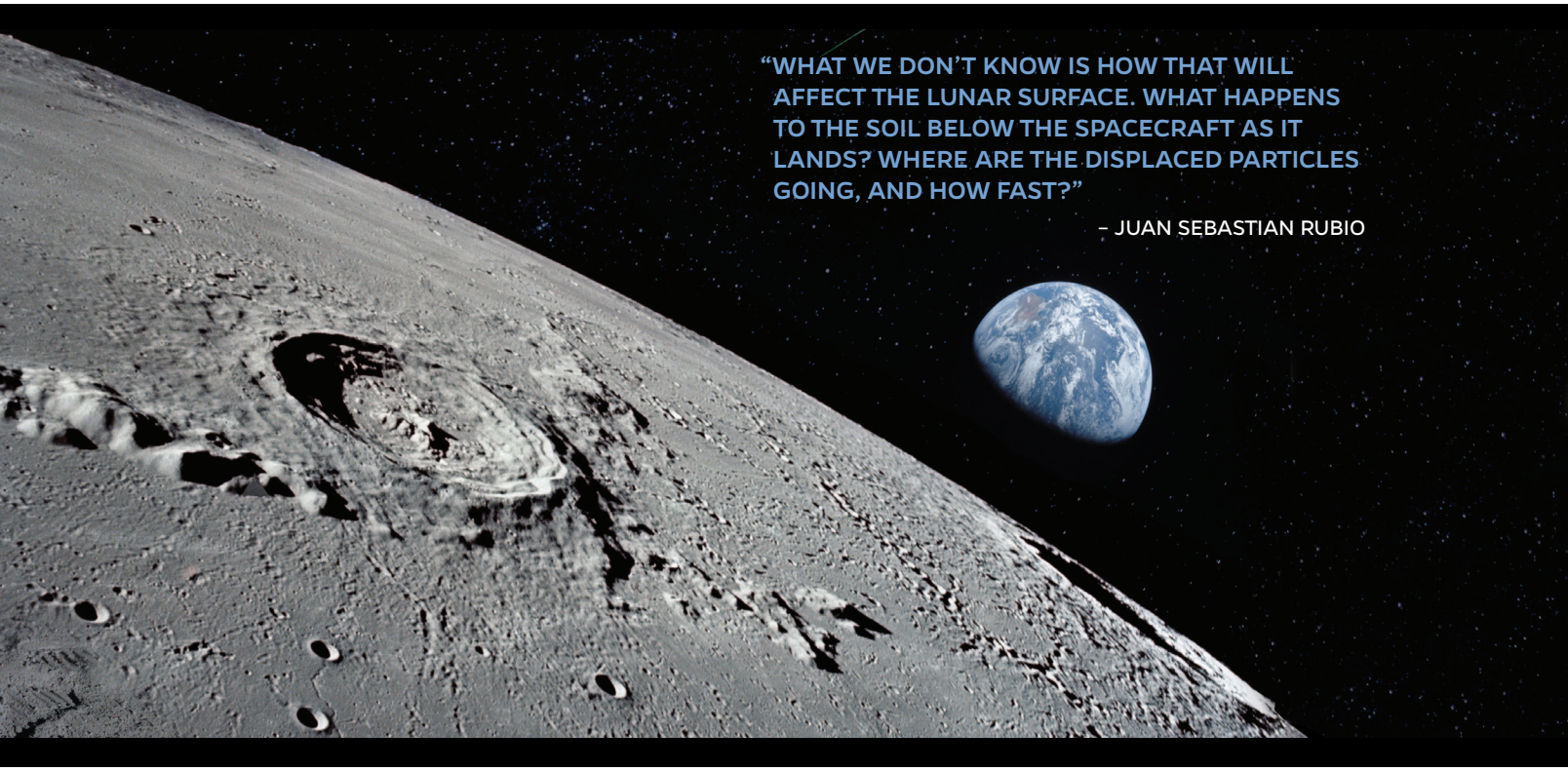
Now back in Baltimore, the team continues work with NASA collaborators on a deeper analysis of its findings. They have presented their work at two major conferences and have plans to publish the results in a peer-reviewed journal.

All agree that working on a large, multidisciplinary research team has been valuable in showing them what life will be like when they leave Johns Hopkins.

"In the lab, we don't work with a huge team on a regular basis. We met so many experienced NASA engineers who gave us suggestions and respected our ideas," says Diaz-Lopez.

One thing is certain: When the next person steps foot on the moon, Johns Hopkins researchers will be among those who made the mission possible.

"Our data is going to be used to guide future missions to the moon, Mars, and other planets," says Rubio. "It is very inspiring for me to be working alongside NASA scientists on a project of this magnitude. Our work will directly impact future space exploration and get us closer to sending the first humans to Mars."



"WHAT WE DON'T KNOW IS HOW THAT WILL AFFECT THE LUNAR SURFACE. WHAT HAPPENS TO THE SOIL BELOW THE SPACECRAFT AS IT LANDS? WHERE ARE THE DISPLACED PARTICLES GOING, AND HOW FAST?"

– JUAN SEBASTIAN RUBIO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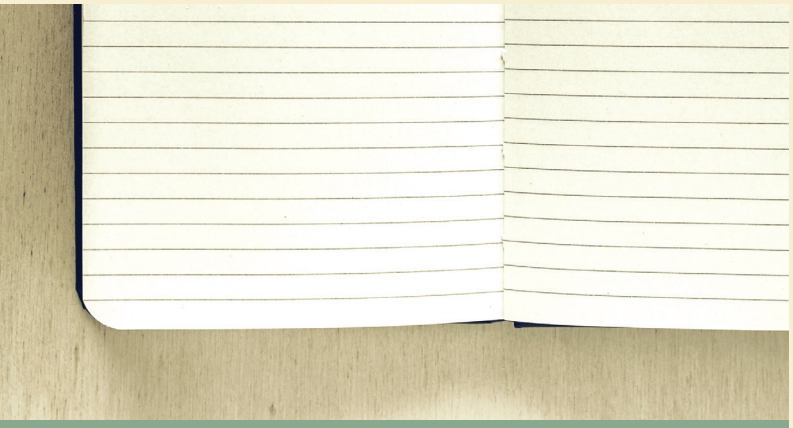
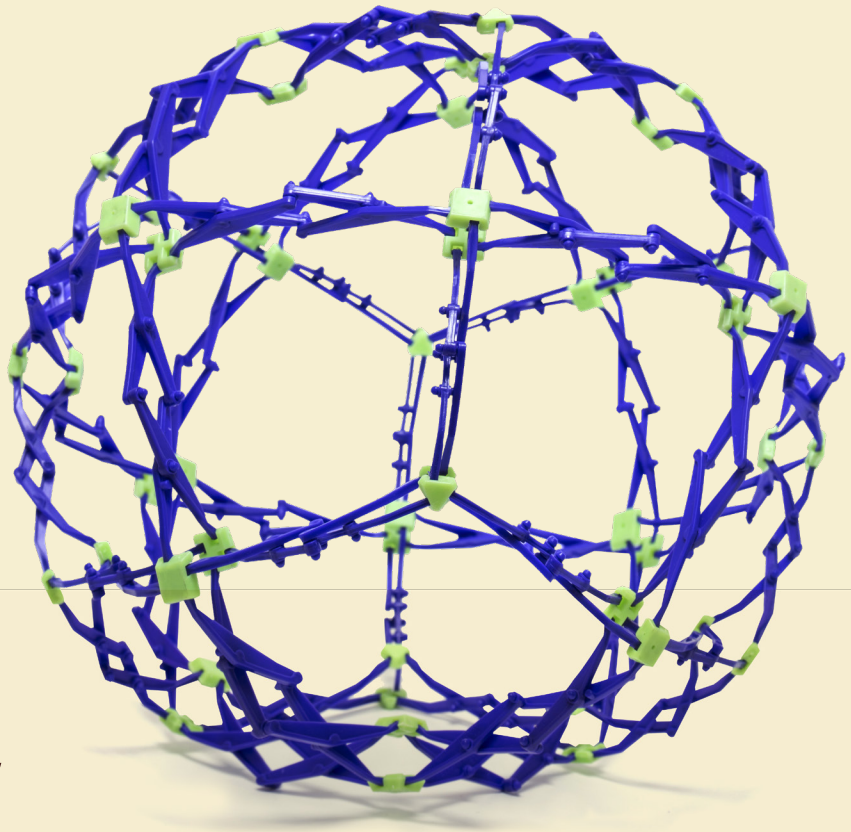




Object LESSONS

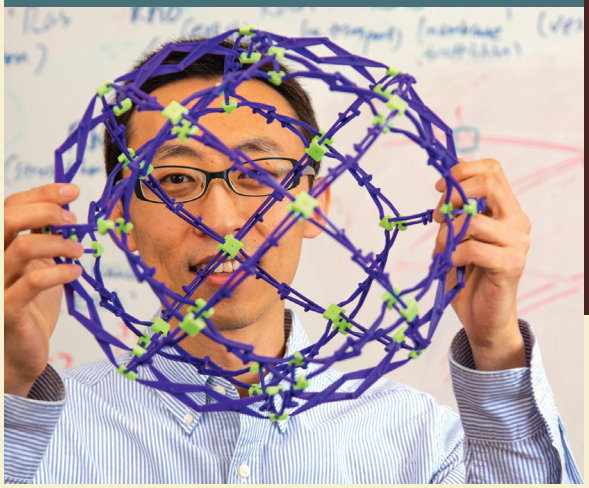
When it comes to everyday objects, engineers often have an uncommon fascination with the way things are designed and the reasons behind their utility. To get a glimpse into this unique way of thinking, we polled a variety of Johns Hopkins engineers and asked them to share their insights on a favorite object of their choosing. Their answers may surprise you.

Compiled by ***Lisa Ercolano***
Portraits by ***Michael Ciesielski***

HOBERMAN SPHERE

Luo Gu

Assistant Professor, Department of Materials Science and Engineering



It's not the best-engineered object, but it's quite useful in my teaching and research. A Hoberman sphere is a transformable structure invented by Chuck Hoberman. It's better known as a children's toy nowadays. I first saw a Hoberman sphere in Chuck's exhibition of his transformable architectural designs in Boston. Its transformation immediately reminded me of the swelling and dehydration of hydrogels, which are important biomaterials used in tissue engineering. Now I use a Hoberman sphere toy to teach the concept of hydrogel in my classes. Oh, and my version glows in the dark.

BATTERY

Marsha Wills-Karp

Anna M. Baetjer Professor in Environmental Health and Chair of the Department of Environmental Health and Engineering

The humble battery plays a major role in my everyday life—from powering my alarm clock, which signals the start of my day, to powering my electric car to transport me to work. The first battery was made in 1800 by Alessandro Volta (the voltaic pile). Although improvements (rechargeable, longer life) have been made over time, they are still based on the simple concept of the conversion of chemical reactions to an electrical current. Hopefully, further improvements in battery life will make it possible to completely replace fossil-fueled cars, reducing greenhouse emissions, and saving the planet.

TOASTER

Gwendolyn Tsai

Undergraduate Student, Department of Mechanical Engineering

The toaster is my favorite appliance in my apartment. As a mechanical engineer who focuses on thermofluids, I like it because it is a really simple example of how heat transfer is integrated into things we use every day. I also think there is something to be said about technologies that are so ubiquitous. It demonstrates that they fill a need with an elegant solution. It also doesn't hurt that I love toast.

WINE

Paulette Clancy

Professor and Head of the Department of Chemical and Biomolecular Engineering

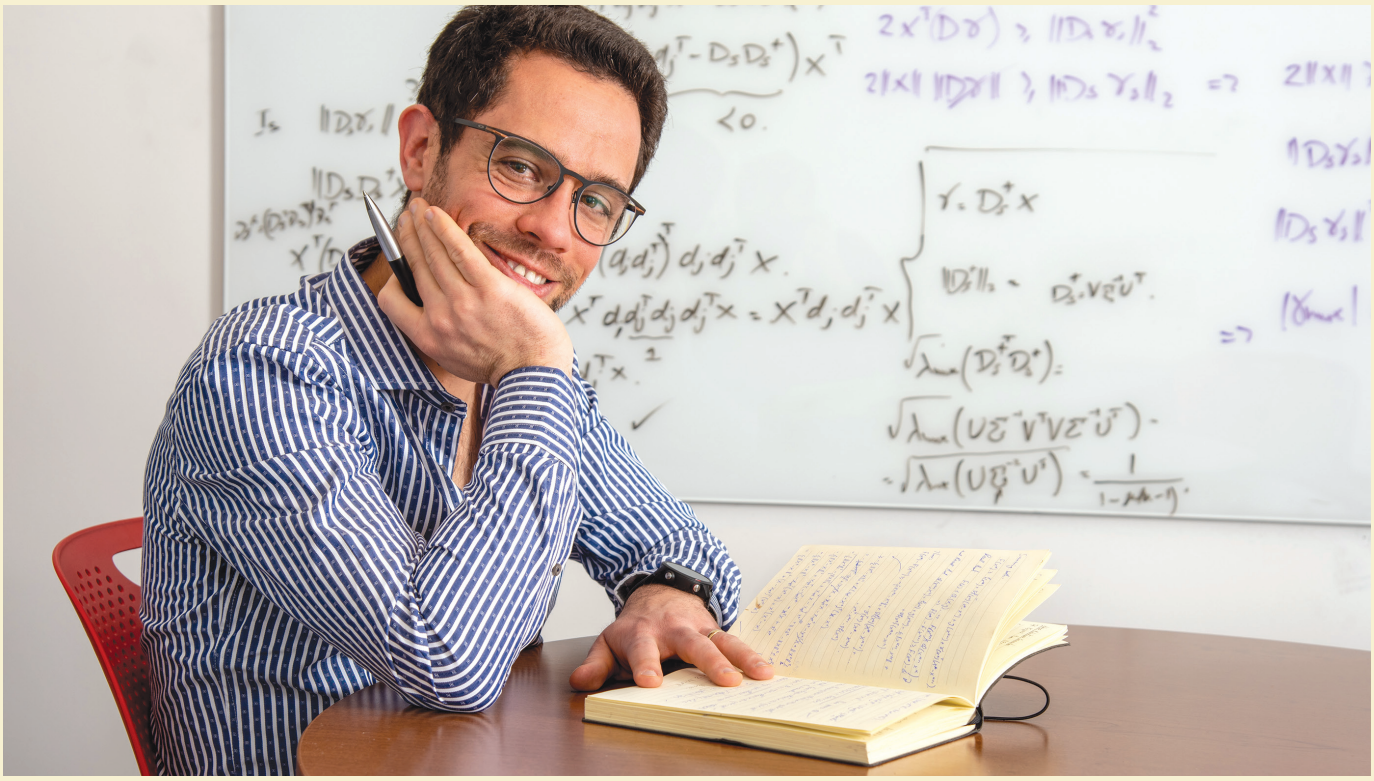
As I imbibe a nice glass of wine on a summer's evening, I sometimes consider that this liquid is the product of fermentation and distillation and a tightly controlled separation processes to ensure safety and a reproducible product—all key components of a good chemical engineering background. By the way, winemaking involves a lot of water and energy use, which is something that wine companies are taking seriously for conservation purposes.

NOTEPAD

Jeremias Sulam

Assistant Professor, Department of Biomedical Engineering

The best-engineered object I use in my daily life is small, portable, and cheap. It is a "thinking-aiding" device. There's always room in my backpack for it, and it is extremely lightweight. The battery almost never runs out, and I can use it for months on end. In a matter of just a few seconds, it enables me to download some vague ideas I have in my mind, and through some not-yet-fully-understood process, it spits back these ideas at me in a better and clearer manner. Most people call this object a small paper notepad.



WORKBENCH

Pedro Irazoqui

Professor and Head of the Department of Electrical and Computer Engineering

I'm only an amateur woodworker, but I'd always been told the most important tool in a woodworker's kit is their workbench, so a few years ago, I built mine, using mostly hand tools, over a period of one month. Since then, I've used it to remodel and improve the two homes it's been in. I've built furniture and even wandered into motorcycle and car maintenance. My workbench is definitely the most important tool in my kit. Having built it myself only makes it that much more rewarding to use.

PAGE-A-DAY CALENDAR

David Flanigan

Program Vice Chair, Systems Engineering

Johns Hopkins Engineering for Professionals

My object is the page-a-day-calendar. I ask for these calendars every holiday from my family, usually featuring places around the world. It serves several functions: As a reminder of a location we've visited (or maybe should visit in the future), as a bookmark, and as a place (on the back) for a daily to-do list or a diagram or concept that we need to discuss during a meeting. If it's a complex situation, we may need a few of these sheets to build a story board to describe the situation.

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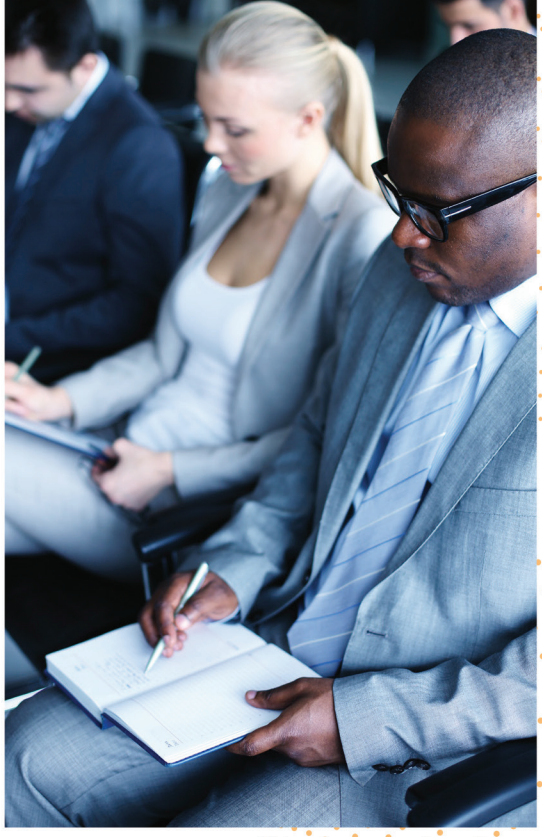

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THWARTING CYBERATTACKS

Threats to cybersecurity loom large in today's world, putting us all at risk of being exploited by bad actors. Whiting School experts are focused on spotting cyber vulnerabilities and defending against them—a never-ending task, where the villains' tactics are evolving just as rapidly as the technology they exploit.

*By **Michael Eisenstein***

*Illustrated by **Dan Page***

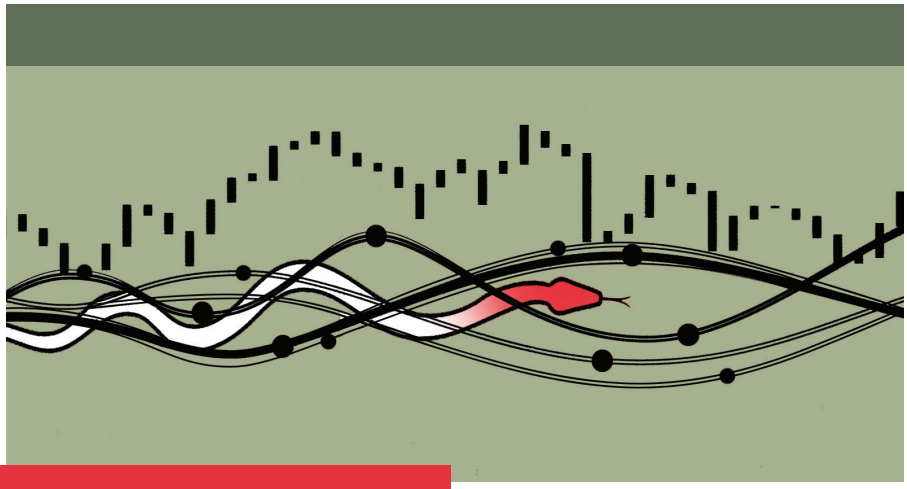
German power company Enercon operates an array of 5,800 wind turbines that can generate up to 11 gigawatts of power when operating at full capacity. But on the morning of Feb. 24, 2022, those turbines went silent.

The timing—the same day Russia began its invasion of Ukraine—was not a coincidence. "They're all connected to a satellite station that was interfered with by Russia as part of this conflict," says Gregory Falco, an assistant professor of civil and systems engineering and a member of the Johns Hopkins Institute for Assured Autonomy. The evidence suggests that the attack was primarily focused on disrupting Ukrainian lines of communication and that Enercon's turbines—which were controlled by the same satellite—were merely collateral damage. "The communication window was shut down, so it couldn't communicate with the turbines, and the turbines died," says Falco.

These kinds of cyberattacks are now part and parcel of modern espionage and conflict, notes Anton Dahbura PhD '84, co-director of the IAA and executive director of the Johns Hopkins Information Security Institute. "It's pretty easy for a country to build offensive cyber capability," he says. "It's also easy to make attribution murky—if they just want to damage their neighbor's banking system but then disavow responsibility." Such attacks can be part of a military offensive, as is now being seen in the Russia-Ukraine war, but they can also take the form of lesser incursions intended to probe a rival's weaknesses or sow chaos.

High-profile, national-scale cybersecurity threats may grab headlines, but there are also myriad ways in which the general public can potentially fall prey to exploitation by bad actors online. Although some of these attacks may be delivered through predictable routes, such as our phones or laptops, we also live our lives surrounded by less obvious—but equally vulnerable—gateways to the internet. "Pretty much anything electronic that you buy nowadays comes with an app for it," says Avi Rubin, professor of computer science and technical director of the ISI.

Research at the ISI and IAA is focused on identifying and defending against such vulnerabilities at every level of America's digital infrastructure—but this is a challenging and never-ending task, where the villains' tactics are evolving just as rapidly as the technology they exploit.



ANTICIPATING CYBERCONFLICT

Long before Enercon's turbines went offline, Dahbura was keeping a close eye on the simmering tension between Ukraine and Russia. In collaboration with Johns Hopkins cybersecurity specialist Terry Thompson, his group runs the Cyber Attack Predictive Index, an online "leaderboard" that ranks the likelihood of one nation dispatching a hacker-led offensive against another.

"That conflict was at the top or close to the top of our index for quite a while," says Dahbura, pointing out prior incursions such as Russia's high-profile, debilitating attack on Ukraine's power grid back in 2015.

There are numerous other international disputes that have the potential to play out in the cybersphere rather than as conventional warfare. For example, Egypt is currently at odds with Ethiopia over a dam project that it believes will interfere with Egypt's water access, and in 2020, Egyptian hackers took over various Ethiopian government websites to issue a series of pointed threats.

The CAPI team assesses the likelihood of each of these conflicts erupting into a cyberattack based on five factors for any given pair of potential "aggressor" and "defender" states. These include the aggressor's motivation and capacity to mount such an attack, their fear of retribution, whether cyberwarfare is part of a broader national security strategy, and the vulnerabilities of the defender. Each of these factors is given a score from one to five, producing a total that reflects the relative likelihood of a future incident. Higher scores indicate higher risk, and the Russia-Ukraine dyad recently achieved the dubious honor of receiving the first "25" score since CAPI's inception in late 2020.

The index is primarily intended as a public resource, to inform and educate general audiences about this rapidly evolving component of international relations and security, but Dahbura also sees the CAPI program as an important educational opportunity. All the rankings are generated by a review board composed of students from the Whiting School's computer science program and the Krieger School of Arts and Sciences' international studies program, with each student assigned a particular region of the world to monitor.

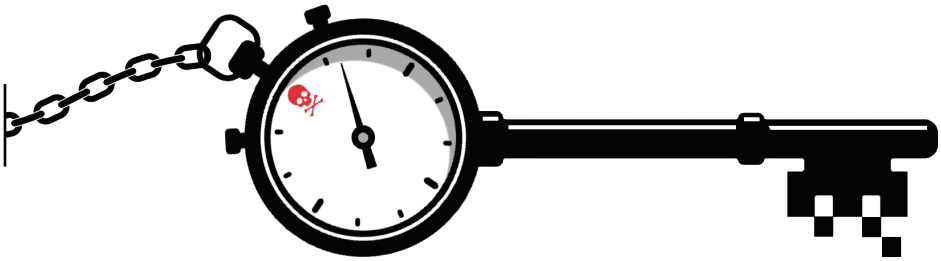
"I'm really big on empowering undergraduates," Dahbura says. "They have so much talent, so much potential, and really relish the opportunity to be involved in these kinds of efforts." After the students present their findings at a weekly meeting with Thompson and Dahbura, the group revises the CAPI rankings accordingly. "Sadly, there are many more additions being made to the list than deletions," says Dahbura.

AVOIDING A VIRTUAL SHAKEDOWN

One commonly used weapon in the cyberattack arsenal is ransomware, which employs malevolent code to lock up or steal a victim's files. Depending on the nature and sensitivity of the ensnared data, the attackers may threaten to either erase or broadly disseminate their ill-gotten goods unless paid a sizable bounty—typically in some form of cryptocurrency.

Falco's group is focused on limiting the impact of such attacks in the context of aerospace systems, utilities, and other essential services. "We try to make sure that things that are operationally critical to different infrastructures are secure," he says, citing such examples as energy providers and the aerospace industry. Early 2021 saw one such attack, when a group of Russia-based hackers known as DarkSide managed to infiltrate and essentially shut down the computer network of the Colonial Pipeline, which provides 45% of the oil supply for the eastern U.S.

In this particular attack, the company promptly paid the ransom—$4.4 million worth of Bitcoin—and received a decryption tool to recover its lost data. But Falco warns that modern ransomware attacks have taken a darker and more nihilistic turn, at least at the level of state-sponsored or -approved incursions. "They're not trying for the money," he says. "They're really going after the control, and they're trying to shut you down and make chaos—and they're pretty good at it." Even a day or two without service could be disastrous for a financial service



company, air traffic control system, law enforcement agency, or energy provider.

A key challenge with fending off ransomware is that it primarily exploits human vulnerabilities, such as an employee being tricked into clicking a link that allows malware to install. Smarter network design could help limit the damage, however. Falco highlights "zero trust" network architectures as one solution.

"That basically means that you should always assume that someone's in your system when you're doing something and act with the knowledge that you can't trust even your own systems for things," he says. This is in contrast to conventional architectures, where trust is baked in and infiltration of one node can give a bad actor ready access to the rest of the network.

But Falco also warns that there is no single strategy that guarantees protection and that vulnerable organizations should pursue multiple parallel strategies and backup plans that evolve along with the threats they encounter. "You have to just assume you're going to get hit, with a lot of cuts over a long period of time," he says. "And you just have to have a whole bunch of ways around the way you're going to get hit."

SAFE AT HOME

From time to time, random civilians might fall prey to a ransomware attack, and Falco notes that the ability to purchase prewritten ransomware code on the so-called dark web can enable attacks of opportunity by dilettante hackers. These are the exception rather than the rule, however. "The days of ransomware gangs attacking single individuals are probably behind us," says Joseph Carrigan, senior security engineer at the IAA and the ISI.

But individuals must be mindful of other vulnerabilities that could expose them to risk from hackers in their day-to-day lives. The rapid proliferation of web-enabled Internet of Things devices is of particular concern.

"There are all these devices that we just buy and plug in, and we don't really think about what constitutes a 'thing' in the Internet of Things," says Carrigan. A particularly savvy and privacy-minded individual might be aware of the vulnerabilities associated with a "smart" security camera or baby monitor while also forgetting about their smart TV, humidifier, and meat thermometer. "Early on, a lot of these things were just pushed out without any consideration for security, creating ample opportunities for exploitation," says Carrigan.

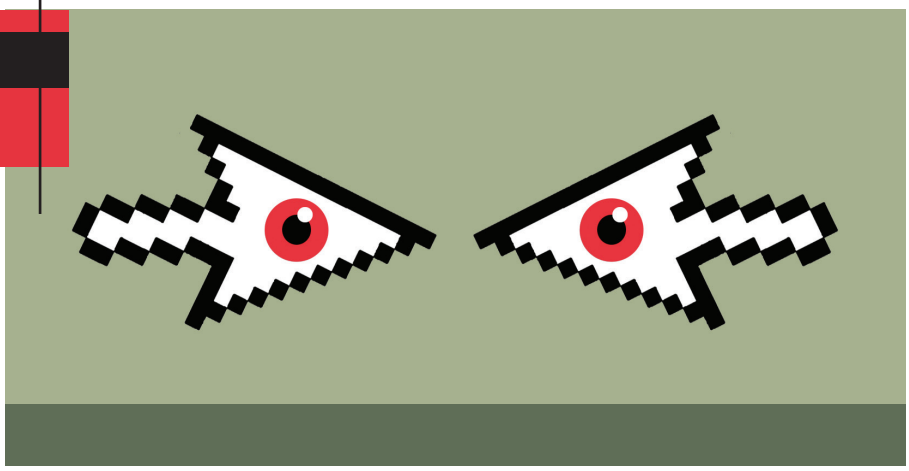
Some are simply direct violations of privacy, like hijacking device microphones or cameras to record individuals without their knowledge. But Rubin also notes that attacks on these vulnerable devices can expose every other device that happens to be on that same Wi-Fi network, including computers, tablets, or phones with sensitive data.

"If someone compromises a device that's on the inside of a network, like an IoT coffee maker or something, now they have the access to the network that an insider would have," he says. These intrusions can even be used to quietly rally armies of internet-enabled "bots," which can then be used to launch far more aggressive "distributed denial of service" attacks that knock entire businesses or even government institutions offline.

"We think we own our own devices, but maybe the device is completely under the control of the Russians or Chinese or someone else," says Rubin. "That's the type of attack that we've seen."

Rubin's group is part of a multi-institutional, $10 million research initiative called Security and Privacy in the Lifecycle of IoT for Consumer Environments, which aims to identify and counter vulnerabilities in these increasingly ubiquitous smart devices. One of the initiative's current priorities is the development of tools to assist in the detection and discovery of networked devices in a given environment—something that can be particularly important with regard to privacy and security in shared living spaces.

FENDING OFF PEEPING BOTS



In some cases, the threat to your privacy could literally be staring you in the face—or perhaps hovering over your backyard. There are well over half a million consumer-operated drones in the U.S., and although most are engaged in harmless hobby videography, some are being deployed for more nefarious and invasive purposes.

Lanier Watkins, an associate research scientist at the ISI, an instructor in Johns Hopkins' Engineering for Professionals programs, and a member of the senior professional staff at APL, cites the hypothetical example of a backyard pool party where teenagers are lounging and having fun—but a neighbor's drone is surreptitiously recording the proceedings from the adjacent airspace. Watkins notes that the current market-leading manufacturer of consumer drones, DJI, offers models with an "active track" mode, which allows them to be trained on and autonomously follow a subject of interest without requiring Wi-Fi support or human intervention. "The drones are controlling themselves," he says. This is a great feature for recording a wedding or capturing skateboarding tricks—but also, unfortunately, for would-be stalkers.

In a 2020 study, Watkins and colleagues set about identifying countermeasures against such unwanted aerial snooping. One strategy that proved remarkably effective was a blast of bright light from an LED spotlight. "If that spotlight is shone directly at the drone for three to five seconds, that causes the drone to kick out of autonomous mode ... and it just sits there hovering," says Watkins. He adds that a similar effect could probably be achieved with a very bright flashlight.

As an alternative, his team was also able to exploit a restraining mechanism built into consumer drones that prevents them from entering airspace in the vicinity of airports or high-security installations, like military bases or the White House.

"It's called geofencing," says Watkins. "And if you try to fly there, it will land or it won't respond." Using a device called a Hack RF One, his team was able to send signals that tricked the onboard GPS systems of DJI drones into thinking they had entered forbidden territory, bringing their autonomous surveillance to an end. Working in collaboration with students at the U.S. Naval Academy, Watkins has also assembled a prototype device that can both detect and immobilize autonomous drones using this kind of GPS "spoofing" attack.

LEARNING THE WRONG LESSONS

However, Watkins also cautions that the same tactics that defend against improperly used drones could also be used to knock out and steal an innocent bystander's expensive hardware. And as more and more autonomous systems enter the consumer marketplace, cybersecurity researchers will need to be prepared for increasingly sophisticated attacks that either subtly manipulate or overtly sabotage those systems.

Machine learning has evolved from being just another flashy buzzword to become the backbone of software tools employed in diverse sectors, including health care, finance, security, and transportation. These algorithms are fed huge amounts of training data, which allow them to identify complex patterns that can then be used to analyze and interpret input collected in "real-world" settings. This could include teaching programs to suggest appropriate therapeutic strategies based on a patient's diagnostic data or educating autonomous vehicles in how to safely follow the rules of the road.

But there are also numerous ways to game these systems, says Yinzhi Cao, an assistant professor of computer science and member of the ISI, whose work is focused on identifying and learning how to counter such "adversarial machine learning"

strategies. For example, one can "pollute" the training data in a way that skews how the algorithm responds. Cao cites the example of Microsoft's Tay chatbot experiment from 2016, which was deliberately trained by ill-intentioned Twitter users to spew racist and anti-Semitic abuse. As unpleasant as this experience was, the same style of attack could have far worse consequences in the context of medical software, for example. "If your diagnosis is wrong, then that could be catastrophic," says Cao.

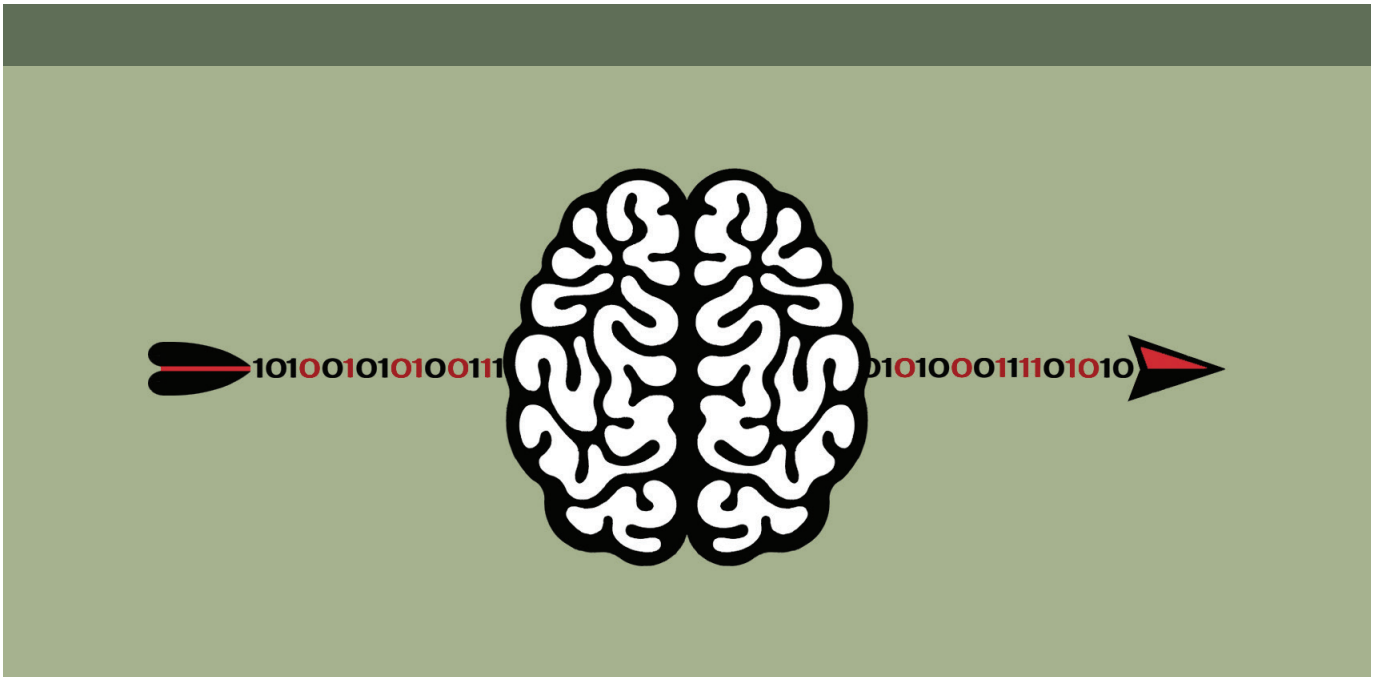
Other attacks take advantage of how machine learning algorithms perform pattern recognition. For example, one can use "patches" to manipulate images in ways that confuse computer vision software, leading the algorithm to interpret those images incorrectly. Even subtle tricks can have surprising effects; in a 2017 study, Cao and colleagues found that changes in lighting conditions could cause the image analysis algorithms used by an experimental autonomous vehicle to make a potentially deadly mistake. "You could make a car crash," says Cao. "Like if it was going left, but then you make it go right."

THE HUMAN FACTOR

One of the best ways to defeat adversarial behavior is to think like your adversary. For example, Cao's team has found that it can make machine learning algorithms more robust by doing its best to deceive and mislead the algorithms. But it is difficult to anticipate every failure mode for a complex system. "As recently as one year ago, we were up to 40- to 50% accuracy in terms of defending against adversarial examples," says Cao. "That's not very high, and it's still an open problem that we need people to solve."

Similarly, as new technologies move to the fore, experts already need to begin thinking about what vulnerabilities they might contain. "The issue is whenever there's something new and everybody goes, 'Ooh, that's cool,' malicious actors say the same thing," says Carrigan. As an example, he cites Silicon Valley's growing enthusiasm for the so-called metaverse, and virtual and augmented reality interfaces in general. "Whatever the metaverse turns out to be, there will be scams," he says. And just like with today's cyberattacks, the stakes could potentially range from violations of personal privacy to actual threats to national security.

But perhaps the most fundamental issue for the cybersecurity experts is that no matter how sophisticated a piece of technology might be, it's only as secure as the people who operate it. "The first kinetic action in 90% of the breaches we see is an email going 'Hey, take a look at this' or 'log into this site,' and then it's all just credential harvesting or malicious attachments," says Carrigan. "It's a fairly standard list of first steps." ■



Space Ambassador

WHEN HE WAS 12, APURVA VARIA WROTE TO NASA TO ASK IF A DEAF person could go to space. It had been his dream since watching a space shuttle launch on the TV in his Texas living room.

The response—"No, not yet"—inspired his career as an aerospace engineer. At NASA's Goddard Space Flight Center, Varia is a mission director for three spacecraft: the Parker Solar Probe, the Interstellar Boundary Explorer, and the Lunar Reconnaissance Orbiter. Varia, who was born deaf, is NASA's first deaf mission director for an uncrewed mission.

On Oct. 17, 2021, Varia took several (weightless) steps toward his dream of space exploration as one of two deaf team members of the inaugural AstroAccess Flight 1 Ambassadors program. The program's mission: to make space flight accessible to all.

The 12 Ambassadors on board the historic weightless parabolic (Zero-G) flight included those with mobility, vision, and hearing disabilities. Their goal is to identify, modify, or develop technology to adapt spacecraft for astronauts with disabilities.

"I can't pinpoint a sound or recognize a spoken word, so we need something that notifies me and other deaf members what is happening in space," explains Varia, who is set to complete his Engineering Management Graduate Certificate in the Engineering for Professionals programs in May.

He is helping to develop wearable technology that displays situational awareness using lights and text. He's also working on a solution to the problem deaf astronauts will face in space—and one he faces every day on Earth: how to communicate when not everyone uses American Sign Language.

On the microgravity flight, a light system told him when it was safe to move. "When I felt weightlessness, it was a magical moment. Even though each flight arc was about 30 seconds, I felt closer to space," says Varia. "I want to continue testing until we have the suitable technologies that allow deaf people to perform equally as hearing people do in space."

Thinking back over his work at the Goddard Space Flight Center, Varia says, "For 13 years, I have loved designing, building, and testing propulsion systems and discovering new science findings." Johns Hopkins' Engineering for Professionals program, he notes, has helped him to expand his technical, project management, and leadership skills.

Fueled by his recent AstroAccess flight and his personal and professional experiences, Varia's lifelong desire to become an astronaut is stronger than ever. "It has been a long and difficult journey because there were struggles that I faced during my life," he reflects. "The important thing for me is to never give up no matter what people say is impossible."

— SARAH ACHENBACH

THIS PAGE: NASA; OPPOSITE PAGE: CHRIS VACCARO

Fiddling Around

JOANNA CLARE, A FOURTH-YEAR MATERIALS SCIENCE AND ENGINEERING MAJOR FROM Syracuse, New York, can delineate differences in, say, polymers and composites in one breath, and in the next, spout off the nuances of jigs, slip jigs, and reels—types of Irish tunes she plays on her fiddle.

Though her worlds seem opposite, Clare sees similarities between the two and plans to pursue both after she graduates, as she's done for the last four years of college.

In February, she released a debut album, *To Keep the Candle Burning*, featuring traditional and newly composed tunes inspired by Irish musicians who have influenced her, from the legendary fiddler Eugene O'Donnell to the acclaimed folk band the Chieftains. Clare plays on the album with seven musicians from Baltimore, plus her longtime fiddle teacher, Brian Conway, from New York.

Her process creating the album resembles her process in engineering. "I especially enjoy the design part of engineering, which starts with a problem and a set of requirements and evolves into brainstorming to diagnose the issue and the iterative nature of designing something that can work," Clare explains.

All parts of the process involved layers of problem-solving. In Irish music, a single track is not a single tune. "A track can include one to four tunes," Clare says, "and musicians typically incorporate tunes with key signatures that harmonically tie them together." Irish music involves improvisation and is often passed down by ear. "Like a game of telephone, Irish music can change over time," Clare explains. "Once you have the rudiments of a tune down, you can do variations on variations and add ornamentations."

This means Clare and her fellow fiddlers, much like engineers, have to make split-second decisions on what to embellish, and when, while engaging in a collaborative trial-and-error process to capture a unique sound. For this, Clare says she pulls from her training in the Suzuki method of classical violin, which taught her to play by ear and helps her perform the highly ornamented Sligo style of Irish music—named after the county town of Sligo, on Ireland's northwestern coast. "Some Irish music sounds soothing in a way that is almost straight," Clare says, "but the Sligo style has lift and swing, and tends to accentuate the first and third beats."

As Clare nears graduation, she plans to keep playing and performing music while applying for jobs with materials and biotech companies. "I like that I have these two outlets," she says. "If I can be creative, I'll be happy." Visit joannaclare.com for more.

— EMILY GAINES BUCHLER

Joanna Clare

“Our main motivation is that there are a lot of opportunities for programs like this, but they’re mostly available in private schools and after-school programs.”

— MICHAEL CHUNGYOUN

Solving Real-World Problems with AI

AS ARTIFICIAL INTELLIGENCE TRANSFORMS THE WORLD, MICHAEL CHUNGYOUN, A PHD CANDIDATE in chemical and biomolecular engineering, doesn’t want public school students to be left behind.

With Nathan Wang ’24, a biomedical engineering major, Chungyoun is developing a hands-on program to integrate AI into classrooms across the United States, beginning this year with high school students in Baltimore City Public Schools.

“Our main motivation is that there are a lot of opportunities for programs like this, but they’re mostly available in private schools and after-school programs,” Chungyoun says.

Hopkins AI in K-12 Education, or HAIKU, is designed to be fun and practical, and foster creativity, its creators say. As students rotate through learning modules that apply AI to history, English, algebra, and biology, Chungyoun hopes they will recognize the value of data-driven thinking across disciplines.

With a $2,500 grant from the Whiting School’s Student Initiatives Fund, Chungyoun and Wang have begun developing HAIKU modules that are relevant to solving real-world problems. Faculty adviser Jonathan Plucker, the Julian C. Stanley Endowed Professor of Talent Development at the Johns Hopkins University School of Education, is helping them stay on a practical track.

“We’re not just going to throw a bunch of theory at students,” Chungyoun says. In one module, students will develop an algorithm to predict weather in a particular ZIP code. Another module produces a football game prediction algorithm. Under development as well is a “Turing test” module that asks students to distinguish between writing prompt responses generated by a classmate and a machine. Also in the works are modules for using AI to predict genome sequencing and fall probability among elderly patients.

The student team will package each HAIKU module as a set of written instructions and a video recording. They plan to make assistance to teachers available in real time to clarify concepts and help teachers become comfortable with the material, Chungyoun says. In addition, high school students will take away “something tangible” from each lesson, such as a predictive weather website or a small sensor they made to measure blood pressure.

In a second phase, HAIKU’s founders plan to develop massive online open courses that introduce AI concepts to high school students without advanced math or programming experience.

A few hurdles remain before HAIKU launches. Chungyoun says additional funding is needed to cover costs, such as stipends for Whiting School students hired to build new modules. In concert with faculty adviser Plucker, Chungyoun also plans a study to evaluate HAIKU’s efficacy.

— STEPHANIE SHAPIRO

A Termite Killer Poses Danger to Environment

TERMITES ARE DESTRUCTIVE AND NOTORIOUSLY HARD TO KILL. Structural fumigation—tenting a house and piping in chemicals to kill the bugs—is the most effective way to do it. But sulfuryl fluoride, a common chemical used for termite fumigation and the only fumigant approved by the Environmental Protection Agency (EPA) for use in residential structures, is a potent greenhouse gas. A team led by Whiting School PhD candidate Dylan Gaeta used atmospheric observations from the National Oceanic and Atmospheric Administration to show that the large majority of sulfuryl fluoride emissions in North America came from California in 2015–2019. Gaeta, whose team presented its findings at the American Geophysical Union's annual meeting, shares insights from their study:

Why is the problem concentrated in California?

California's year-round warm climate is favorable for termite colony growth, both indoors and in nature, so it is very common for buildings there to have termite infestations that require fumigation. In addition, California is the only state that publicly releases a statewide record of sulfuryl fluoride use.

Aside from being a greenhouse gas, is sulfuryl fluoride bad for human health?

The gas is often referred to as a pesticide or an insecticide, but more generally, it is a biocide: It will kill all living organisms that are exposed to it at sufficiently high concentrations for a sufficiently long period of time. That includes humans, pets, plants, and wildlife. The EPA has set an exposure limit of 1 part per million for sulfuryl fluoride, and fumigators must ensure that every room in a fumigated structure falls back below 1 part per million before humans and pets can reenter. There have been several documented cases of inadvertent deaths caused by sulfuryl fluoride fumigations, and the EPA is currently reviewing public health and safety regulations for its use.

What are the climate implications for sulfuryl fluoride use?

Sulfuryl fluoride is a potent greenhouse gas that is entirely human-made, with no significant natural sources. Sulfuryl fluoride was first discovered in ambient air in La Jolla, California, prompting a series of seminal studies. The results were published in 2008–2009, with the main takeaway that sulfuryl fluoride has a much longer atmospheric lifetime than initially thought: 36 (plus or minus 11) years.

With such a long life span in the atmosphere, the global warming potential was revised upward to 7,510 over a 20-year interval. In other words, 1 ton of sulfuryl fluoride traps as much heat in the atmosphere as 7,510 tons of carbon dioxide. After these studies were released, the Intergovernmental Panel on Climate Change added sulfuryl fluoride to its list of greenhouse gases in 2013, and the California Air Resources Board added the chemical to its list of short-lived climate pollutants. However, global emissions of the gas have continued to rise. The gas has been left out of most major greenhouse gas inventories and emissions reductions targets.

What real-world impact do you hope this research will have?

We would like to see sulfuryl fluoride included in future greenhouse gas inventories at the national, state, and local levels.

— INTERVIEW BY DANIELLE UNDERFERTH

Using Food to Fight Anti-Asian Hate

WHEN TIM MA, MS '05, LEFT HIS JOB AS A SENIOR HARDWARE ENGINEER WITH RAYTHEON TO ATTEND culinary school, his parents, both Chinese immigrants, worried. After all, they had "come to America to work insane hours in a Chinese restaurant so their kids wouldn't have to work in restaurants," Ma says.

But Ma didn't let his parents' aspiration for him to "work as a doctor, lawyer, or engineer—that was their American dream," he says—deter him from his passion. He negotiated an engineering consulting gig, snagged an unpaid internship at a Michelin-rated eatery, and enrolled in the French Culinary Institute (now the International Culinary Center) in New York City. "Before this, I had never really handled a knife," says Ma.

After culinary school, Ma and his wife moved to balmy St. Thomas to slog long hours working and learning in the finest restaurants while spending downtime on the beach, dreaming up plans to open a restaurant. But moving back to the continental U.S. came with obstacles. "I'd barely been a line cook, and we struggled to find funding," Ma shares.

Eventually, Ma bought a restaurant off Craigslist in northern Virginia and went on to run a series of bistros serving contemporary eclectic cuisine. In 2020, when the coronavirus pandemic hit, Ma surprised everyone with a return to his roots. He opened a temporary Chinese takeout restaurant, Lucky Danger, in Washington, D.C., which he later relocated to Arlington.

Part of the appeal came from the pandemic-fueled business opportunity in takeout. But another came from an intrinsic interest in his heritage.

"People in this country perceive Chinese food as takeout, and I wanted to explore the food's history and what it means to be Chinese-American," Ma explains.

Ma describes Lucky Danger as "updated Chinese-American takeout." His menu features traditional dishes like spring rolls with twists like whitefish with pickled mustard greens.

With plans underway to open a second Lucky Danger in Washington, D.C., Ma not only cooks and sells food but also uses it to combat the wave of anti-Asian attacks coinciding with the pandemic. "The situation reached a boiling point," Ma says. "I had no choice but to help."

He and another chef, Kevin Tien, devised a way to donate proceeds from takeout to organizations fighting anti-Asian crime while teaming up with chefs nationwide to do the same. "We raised more than $200,000, and we're applying for our nonprofit status to continue the work," Ma says.

"We're just using what we know how to do: cook food," he adds.

— EMILY GAINES BUCHLER

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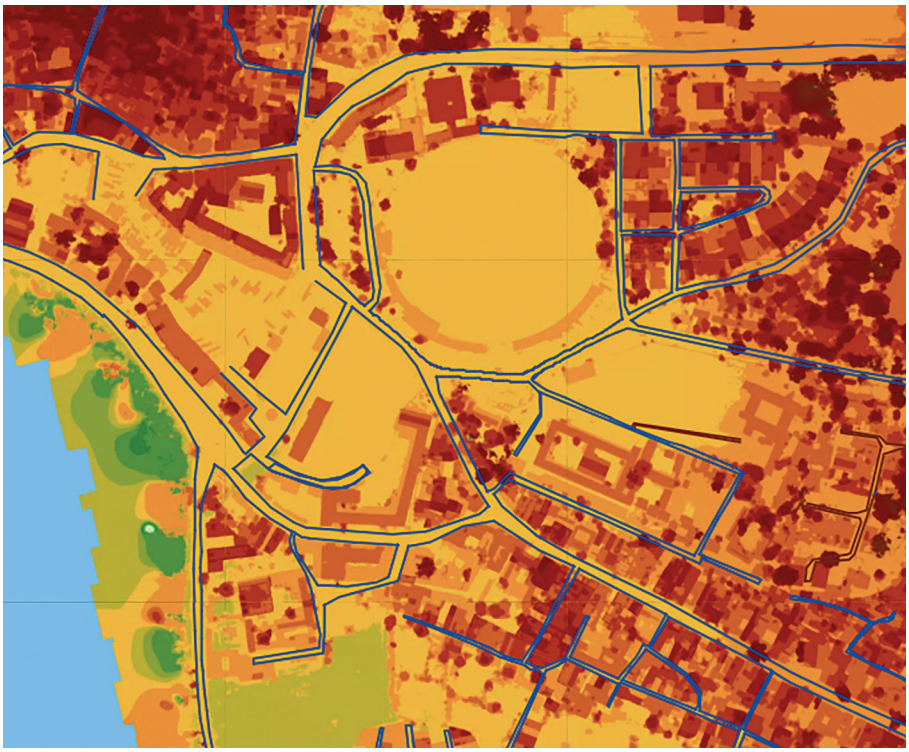
Ready for Takeoff

Ayushi Mishra



AYUSHI MISHRA, MS '16, GREW UP THE DAUGHTER OF ACADEMICS. HER FATHER HELD A DOCTORATE IN physics; her mother, a doctorate in chemistry. But it is still a long way from the small town in India where she grew up to Johns Hopkins University. When it came time for Mishra to decide what to study, biomedical engineering was the answer. And, in that pursuit, there was only one school for her.

"Johns Hopkins was the place to be," says Mishra, who founded her first startup, Marigold Health, while still a graduate student at the Whiting School. She also met computer science student Utkarsh Singh, with whom she has founded a second startup, DronaMaps, where she serves as chief operating officer today.

Mishra leveraged her interests in emerging technology and product design to found Marigold Health, a mobile platform that uses artificial intelligence to help patients with mental health challenges. The digital health startup, which innovates on traditional one-on-one peer coaching to give patients the ability to converse with each other through text-based chats, found its footing with the support of the National Institutes of Health and recently received seed funding to expand to three states.

To make DronaMaps a reality, Mishra moved back to her home country, where she has hit her stride as engineer and as an entrepreneur. DronaMaps is a policy-level decision support system for government and business that is based on 3D maps captured by drones.

Mishra helps integrate historical data and techniques borrowed from geospatial information systems data from on-the-ground sensors, and even closed-circuit television, to deliver deep insights for sustainable development and governance. Mishra and Singh were both recently named to the *Forbes* 30 Under 30 list of up-and-coming businesspeople in Asia.

DronaMaps offers a centralized system of data interoperability for a range of public services. It has helped governmental leaders improve property tax equity and fairness in hard-to-reach areas of India, aided farmers in maximizing crop yields, and helped direct home-improvement grants to 16,000 households in poverty-stricken areas of the country. The system has also been crucial to India's response to COVID-19 by tracking patients village by village and using WhatsApp chat, rapid response team tracking, and predictive analytics for vaccination and hospital bed monitoring.

"Such integrated data analysis is only in its early stages. Combining valuable but disparate information to form a backbone of three-dimensional, high-resolution data, such grounded-in-reality applications could change citizen services forever," says Mishra. "Using drones to democratize mapping for initiatives for high-impact organizations, DronaMaps' analytics provide a level of actionable insights not possible before."

Mishra ties the success of DronaMaps back to her formative experiences at Johns Hopkins, the collaborators she would meet, and the mentorship of professors like Lawrence Aronhime at the Center for Leadership Education, who inspired Mishra to believe in herself.

"The most important thing that Johns Hopkins provided," Mishra says, "was a sense of possibility."

— ANDREW MYERS

Numbers Game

THINK OF BASEBALL, AND YOU THINK OF NUMBERS. THE LAST PLAYER TO bat .400 was Ted Williams in 1941. No one's come close to repeating Joe DiMaggio's 56-game hitting streak in that same year.

Math's importance to the sport is enduring. The statistical recap of each game (or box score) took shape in the 1860s, mere decades after the baseball's invention. Expanding and refining data have gone hand in hand with the sport's growth in the 19th and 20th centuries.

Baseball's love affair with statistics has deepened in recent decades, as baseball teams have invested in an innovative empirical analysis of statistics, driven by burgeoning technology. (The bestselling *Moneyball* and its 2011 film adaptation illustrated how organizations now cover this competitive edge.)

Being part of baseball's data-driven present and future has proven irresistible to Neil Gahart '18. He was promoted in November 2021 to his new position as coordinator of major league analytics for the Miami Marlins. In that role, he provides a crucial link between those who play the game and his colleagues who break down a dizzying array of data.

Innovations in gathering and analyzing data are key, Gahart says. State-of-the-art technology—such as the Hawk-Eye video system installed at all 30 major league stadiums—offers a granular view of everything that happens on the field. Google Cloud feeds this voluminous information into powerful databases for analysis.

"More sophisticated devices that can track and store a larger amount of data mean there are a lot more numbers we can associate with the game," he says. "That leads to opportunities to use those numbers to drive insights about what's going on—and make better decisions."

As an undergraduate at the Whiting School, Gahart was an applied mathematics and statistics major with an abiding love of playing and watching the game. "I was a huge baseball fan growing up," he recalls. He sees his job as "a very cool intersection of two passions."

Johns Hopkins engineering classes were "very demanding," he says, "and because they're demanding, you get a lot out of them." But outside the classroom, Gahart acquired other skills relevant to pursuing a baseball career, including an internship with the Baltimore Orioles.

A baseball-themed mathematical research project provided another key moment in Gahart's journey. Scheduling games to maximize competitive fairness and minimize the impact of factors such as travel is a perpetual headache for professional leagues. So an initiative started in 2012 by the Whiting School's Anton Dahbura, PhD '84, executive director of the Information Security Institute and co-director of the Johns Hopkins Institute for Assured Autonomy, in collaboration with Associate Research Professor of Applied Mathematics and Statistics Donniell Fishkind, deployed the power of mathematical optimization to build better schedules.

Students from Fishkind's Introduction to Optimization course, including Gahart,

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helped create an improved slate of games for a number of minor league organizations.

"That was the first time where the intersection of [mathematics and baseball] became very clear to me," Gahart recalls. "Having access as a second-year Hopkins undergraduate for these conversations with professors and having the opportunity to do research is an extremely cool thing."

"More sophisticated devices that can track and store a larger amount of data mean there are a lot more numbers we can associate with the game. That leads to opportunities to use those numbers to drive insights about what's going on—and make better decisions."

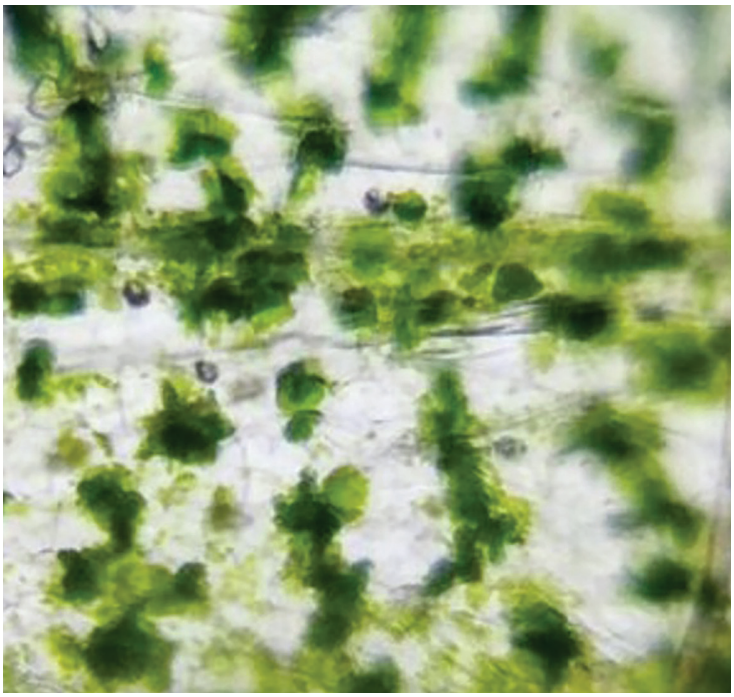
— NEIL GAHART

Gahart's new role with the Marlins brings more responsibility for finding ways to use data to help the team climb the standings. Baseball is still a sport where tradition (and even superstition) hold sway, and accumulated wisdom from years of playing the game is revered. Success as an analyst means getting crucial insights to everyone involved in a way that resonates.

"You want to make sure that the people who really need those insights are aware of them—and understand them at a fundamental level. You want to build relationships with people. Value their input. Value their insights," says Gahart.

Wins and losses remain the most important statistic for everyone, so that gives Gahart an appreciative audience. "Everyone in baseball is trying to win," he says. "To try to find an edge. That incentive for every person who's so hungry to win is to try to do everything that will help them achieve that goal."

— RICHARD BYRNE



Blooming Opportunity

Ikbal Choudhury

USING LOW-COST BUT ACCURATE TOOLS, IKBAL CHOUDHURY '21 AND HIS PARTNERS are bringing science education and environmental conservation to young students and teachers with limited resources through a non-profit company Choudhury co-founded in 2020 called the Open Field Collective.

The non-profit hosts a virtual microscopy camp and an algal bloom monitoring program that uses paper microscopes that cost less than $2, a smartphone, and few small accessories. In the algal bloom program, students analyze samples collected from local water sources and upload findings to a database on the non-profit's website. This data can help monitor the environment long term, as algae are a water quality indicator species.

Since its launch, the Open Field Collective has trained more than 150 teachers and reached more than 600 children across the United States, India, and Bangladesh through the algal bloom program. Leaders are also planning a pilot in Nepal.

— GINA WADAS

‘Attuned to the Clay’

“It’s a journey from clay particles to a mound of clay on the wheel; from an imagined idea to a form; and, by fire, from greenware [water soluble] to bisque and all the way to a vitrified ware.”

— TAMER ZAKI

TAMER ZAKI IS AN EXPERT ON TURBULENCE AND HOW FLUIDS TWIST AND WHIRL—WHEN WAVES break on the ocean surface or the wind kicks up during a storm. But on evenings and weekends, this professor of mechanical engineering who studies the movement of air and water is immersed in another element—earth—as an accomplished potter. To Zaki, a lump of cool, wet clay is ripe with possibilities.

“Pottery fulfills a different and instinctive desire to build something tangible, or physical, to engage my tactile senses,” he says.

Zaki began working with clay in 1999 while a student in mechanical engineering at Penn State. He found pottery similar to the research process: You imagine something and proceed to create it.

“It’s a journey from clay particles to a mound of clay on the wheel; from an imagined idea to a form; and, by fire, from greenware [water soluble] to bisque and all the way to a vitrified ware,” he says.

Zaki especially cherishes what he calls the “relationship” between potter and clay, which he shares with other ceramics enthusiasts by teaching classes at Baltimore Clayworks.

“You must be attuned to the clay during every stage of the process, making sure it has the right elasticity, consistency, and moisture. The feel tells you about its strength and how far you can stretch it. The material also has memory: On the wheel, it twists in a spiral imprinted by the potter’s hands and winds back as it dries. It's thermally stressed when it’s fired, and some of that stress is relieved when cooled,” he says.

— LISA ERCOLANO

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Better Bioplastics, Cleaner Beaches

Beach cleanups and trash wheels are great, but what if the materials used to make the plastic packaging littering beaches and waterways were not only biodegradable but also made from nature itself—from plants?

Alden Murphy, a master's degree student in materials science and engineering, is looking into methods for developing a new kind of bioplastic to fill that niche. Inspired by the cans, bottles, straws, and other detritus she has seen littering the beaches of Tybee Island, Georgia, where she grew up, she wants to create food packaging that is not only environmentally friendly but also costs less and appeals to consumers.

"I decided it may be nearly impossible to keep people from littering and focused instead on making trash more biodegradable and safer for the environment," says Murphy.

— AMY WELDON