EQuad News

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WATER & ENERGY

PRINCETON

School of Engineering
and Applied Science

DEAN'S NOTE

Legacy of impact drives future growth

In the 50 years since the first Earth Day in 1970, Princeton University's extraordinary community of scholars, alumni, and global collaborators have investigated our planet's systems and invented solutions that allow us to thrive more sustainably within those systems. This combination of fundamental research and practical innovation around issues of great importance for humanity is one of the qualities that attracted me to Princeton to become dean of the School of Engineering and Applied Science. Since I started here September 1, I am all the more impressed and energized by this community and its potential to address significant challenges to benefit humanity through engineering and technology.

This issue of EQuad News looks briefly at two important slices – water and energy – of Princeton's work in environmental sustainability, both of which include strong leadership from across the engineering school. Princeton is now planning major investments in environmental teaching and research, including an entire new campus neighborhood that will further enhance the cross-disciplinary interplay of science and engineering that is so critical to reaching truly effective solutions for our future. This vision for collaboration and impact also is driving our growth in bioengineering, data science, robotics, and urban systems.

Across all these areas of engineering, I intend to amplify our impact by growing entrepreneurship and our engagement with industry and by increasing diversity and inclusion so that we are maximizing the talent and breadth of perspectives we bring to bear on urgent issues.

I am eager to hear from you and discuss these exciting areas of research and innovation in more detail. Please follow and engage with us on social media or email me at goldsmith@princeton.edu.

Andrea Goldsmith
Dean
Arthur LeGrand Doty Professor
of Electrical Engineering

Photo by Nick Donnoli

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Note on alumni class years
Following Princeton University convention, undergraduate alumni are indicated by an apostrophe and class year; graduate alumni, whether master's or doctoral, are indicated with a star and class year.

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Photo by David Kelly Crow

ANDREA GOLDSMITH, ENTREPRENEUR AND LEADER IN WIRELESS COMMUNICATIONS, BECOMES DEAN OF ENGINEERING

Andrea Goldsmith, an expert in wireless systems who has served in leadership roles at Stanford University, became dean of the School of Engineering and Applied Science on Sept. 1.

Previously, Goldsmith was the Stephen Harris Professor of Engineering and professor of electrical engineering at Stanford. Recognized for contributions to the field of wireless communications, she has co-founded and served as chief technical officer for Quantenna Communications and Plume WiFi. She is a member of the National Academy of Engineering and the American Academy of Arts and Sciences, two of the highest honors in U.S. academia.

"She is a brilliant and creative scholar, a successful entrepreneur, and a strong advocate for diversity and inclusion in the academy and industry," said President Christopher L. Eisgruber '83. "I expect that she will be a superb dean for Princeton's School of Engineering and Applied Science, and I am delighted she has agreed to join us."

Goldsmith succeeded Emily A. Carter, who became executive vice chancellor and provost at the University of California-Los Angeles, on Sept. 1, 2019. Former dean H. Vincent Poor '77 served as interim dean. Goldsmith also joined the Princeton faculty as the Arthur LeGrand Doty Professor of Electrical Engineering.

"The opportunity to steer creation of new buildings and a new neighborhood for the engineering school, launch interdisciplinary institutes in bioengineering and data science, grow the number of engineering faculty and students significantly, and foster innovation and entrepreneurship within engineering and more broadly throughout Princeton, is unique and extremely compelling," Goldsmith said. "These initiatives have the potential for lasting impact not only for Princeton, other universities, and the engineering profession, but for people everywhere who will benefit from the new knowledge and innovations that we will create."

Goldsmith is a leader in information theory and communications, focusing on wireless communications, cyberphysical systems, and neuroscience. She developed foundational mathematical approaches for increasing the

For longer versions of stories in this section, see **engineering.princeton.edu/news**

ANDREA GOLDSMITH (continued)

capacity, speed, and range of wireless systems, techniques now widely used in cellphone networks and Wi-Fi. She also started and led several multi-university research projects to advance this work.

She also spearheaded major initiatives at Stanford in the in the electrical engineering profession to increase diversity in science and engineering.

Goldsmith joins Princeton at time of growth in engineering and applied science, including initiatives in bioengineering, data science, the future of cities, and robotics and cyberphysical systems. The University also plans construction projects, including buildings for departments and a bioengineering institute, to support these initiatives and increase Princeton's contributions to the region's innovation ecosystem.

"I am honored to be selected for this role, and excited to help execute Princeton's bold and compelling vision for SEAS," Goldsmith said. "I'm very much looking forward to working with Princeton faculty, students, staff, leadership, and trustees to realize that vision and ensure that together we are achieving maximum benefits for humanity."

ENTREPRENEURSHIP IN A PANDEMIC – eLAB PROGRAM SHOWS THE POWER OF PIVOTS

Princeton students and alumni who founded the fashion company Kotami planned to spend the summer in Princeton on branding, content creation, and setting up their store while manufacturing occurred in Brazil. The leaders of Manamé, a company aspiring to revolutionize shipping in Africa, planned to develop their software in Princeton and test it with consumers in Africa.

The coronavirus pandemic changed all that.

The two teams were among six startups in this year's eLab Summer Accelerator, a program run by the Keller Center for Innovation in Engineering Education. Assembling teams in Princeton to work with mentors, guest speakers, and advisers has been a key part of the program for eight years. But the COVID-19 pandemic forced teams and organizers to adapt. In online presentations at the Aug. 12 Demo Day, the teams showed how they had risen to meet difficult circumstances.

"Being an entrepreneur is difficult under any circumstances," said Cornelia Huellstrunk, the center's executive director. The teams' ability to thrive in the face of such instability was "a testament to their commitment to their ideas and wishes to make the world a better place."

This year's eLab included the following teams:

Lumentee – An app to broaden access to college
An app to make college more accessible by giving students from underprivileged high schools a forum to engage directly with current students at institutions

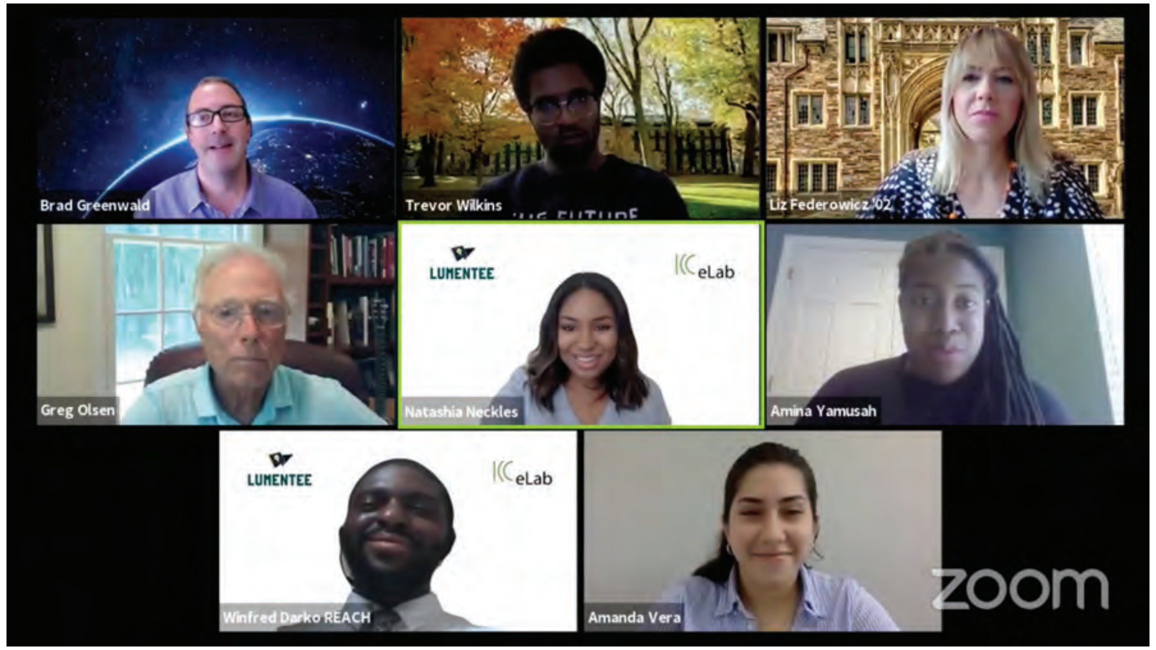
Claudius Legal Intelligence – Artificial intelligence and prediction that helps lawyers make informed decisions
A way to harness artificial intelligence and predictive analytics to provide lawyers and law firms with data-driven guidance as they make decisions about taking cases to trial and negotiating settlements

Manamé – An African logistics coordination platform that connects cargo owners and transporters
A digital marketplace through mobile apps for cargo owners to seamlessly connect with transporters and quickly get their goods to the desired destination at much lower costs than traditional methods

Kotami – A fashion line bridging the gap between sustainability and style
An affordable, genderless, size-inclusive clothing brand that reflects social justice, ethical manufacturing, and commitment to sustainable materials and fair labor practices

PhaseOne – A platform giving pharmaceutical companies analytics about emerging biopharma products and technologies
A tool to help pharmaceutical companies build their drug development pipelines

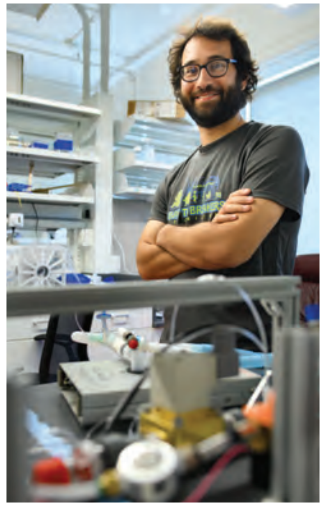
The Crumpet Society – A food service reinventing the English griddlecake for the 21st century
A delicious product using locally sourced ingredients and sustainable packaging.
– By Beth Jarvie



The Lumentee team, which developed an app to ease the college admission process, was the first to present at the 2020 eLab Demo Day. At the end of their presentation, team members responded to questions from an expert panel, shown here.

‘LIFE-SAVERS FOR OUR FRONTLINE’ — IN PANDEMIC, STUDENTS AND FACULTY RACED TO CREATE INNOVATIVE PROTECTIONS AND DEVICES

Photo by Sameer A. Khan/Fotobuddy



Tom Zajdel, a postdoctoral researcher in mechanical and aerospace engineering, was part of a team that designed a low-cost ventilator that could be assembled from readily available parts.

Early on the morning of April 23, graduate student Matt Heinrich received an urgent text from Princeton Medical Center.

The hospital needed stretchable, reusable, full-face-and-neck shields for the patient care units, and it needed them fast. Such covers are much more complicated than simple plastic shields and must integrate seamlessly with existing helmets. Heinrich had just sent over a prototype he had made, and hospital administrators asked for an immediate delivery. Despite having an adequate supply just days before, the hospital had seen such a sharp, sudden increase in the number of patients with COVID-19 that its supply of shields had dwindled to three.

“They said, ‘How many can you make?’” said Heinrich, a doctoral candidate in mechanical and aerospace engineering. “I said, ‘How many do you need?’”

The hospital asked for 10 immediately and another 10 in a few days. Heinrich quickly set to work. By the afternoon, he delivered the first batch to waiting medical workers. That night, his friend Thomas Schaffner, a 2018 master’s graduate, stayed up to make another 10. Over the next few days, a network of volunteers sorted and cut parts and fastened them together for an initial batch of 100.

Heinrich and his friends are part of a group of researchers, staff members, and students assembled by Professors Daniel Cohen and Daniel Notterman to address the urgent need for medical workers’ protective equipment during the COVID-19 pandemic. The work is part of a greater effort by the Princeton University community to support efforts regionally and internationally to combat the disease. Many of the efforts, which span nearly all departments, began soon after the outbreak and continue today.

Through the spring and summer, teams of researchers, staff, and students coordinated by Cohen and Notterman built face shields for hospital workers, face and neck shields for hospital workers’ protective equipment (called PAPRs), and an open-source, economical ventilator made from off-the-shelf parts.

Cohen said he was proud of his colleagues’ response and hoped their work would continue through the pandemic and beyond. **– By John Sullivan and Catherine Zandonella**

For more on COVID-related research and service, see **bit.ly/COVID-action**

Senior research specialist Eric Mills *16 volunteers for the Princeton First Aid & Rescue Squad, an independent, nonprofit 110-member group of emergency medical technicians serving the Princeton area. He’s one of numerous members of the Princeton University community, mainly staff and students, who volunteer their time with area rescue crews. Mills, who received his doctorate in electrical engineering from Princeton and works in the Micro/Nano Fabrication Lab, joined the rescue squad after training as a volunteer with the Princeton fire department.

Photo by Steven Schultz

PRINCETON TEAMS OFFER RESEARCH AND INNOVATION IN COVID BATTLE

On April 1, as the COVID epidemic threatened to overwhelm area hospitals, Andrew Leifer was looking for a way to help. The Princeton University physicist connected with doctors at the University of Pennsylvania Health System in Philadelphia who were working to prevent a looming shortage in machines used to keep patients breathing.

Penn Medicine, which runs hospitals in Pennsylvania and New Jersey, needed specialized machines to monitor the breathing patterns and flow of oxygen to patients undergoing non-inavsive ventilation, a form of respiratory support that is gentler on the lungs and has caught on in popularity during the COVID crisis. The hospitals needed the machines to meet exacting standards, and they needed them fast. Plus, there was a catch: Parts used to build the devices were nearly impossible to find. So, Leifer and his colleagues at Princeton would have to improvise.

They did. In a few weeks, a collection of scientists designed, prototyped, and tested the new machine. The created new supply chains for repurposed parts, fine-tuned subsystems in the labs of Princeton's materials institute, and built the new machines in Jadwin Hall. Within a month, the team had produced 50 new machines.

Since the COVID epidemic shut down much of the country, the Princeton community has responded in many ways to help battle the disease. Researchers have refocused their efforts, staff members have routed emergency supplies to hospitals, and students and faculty have made protective equipment for medical workers.

“We have had involvement at all levels: faculty, students, postdocs, staff,” said Leifer, an assistant professor of physics and neuroscience. “It’s amazing.”**– By John Sullivan**

Photo courtesy of the researchers

A team of Princeton volunteers designed and built monitors used by medical workers to care for patients with COVID.

SPEECH CREATES SPRAY OF DROPLETS WITH IMPLICATIONS FOR DISEASE

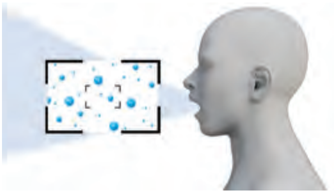
In studies with implications for airborne disease transmission, Princeton researchers have described how speaking forms tiny droplets of saliva and creates airflow that carries the droplets from the speaker’s mouth. The studies provide insight for medical researchers working to prevent the spread of respiratory diseases such as COVID-19.

Using high-speed imaging, the researchers reported in the journal Physical Review Fluids that when our mouths produce speech sounds, a film of lubricating saliva initially spreads across the lips. As the lips part, the liquid film breaks into filaments. Airflow from the lungs stretches the filaments until they rupture and disperse as miniscule droplets — in fractions of a second.

The researchers also found that conversation creates a conical airflow that carries tiny droplets from a speaker’s mouth. Writing in the Proceedings of the National Academy of Sciences, the researchers concluded that indoor conversations can spread exhaled material at least far as, if not beyond, guidelines recommended by the World Health Organization (1 meter) and U.S. officials (2 meters, or about 6 feet). The work examined particle flow in an interior space without good ventilation. The researchers said masks play a critical role in disruption of the jet-like air flow from a speaker’s mouth, preventing the quick transport of droplets farther than 1 foot.

The research was led by Howard Stone, the Donald R. Dixon ’69 and Elizabeth W. Dixon Professor of Mechanical and Aerospace Engineering, and Manouk Abkarian, a research director at the French National Centre for Scientific Research.

Illustration by Matilda Luk



Princeton’s Howard Stone and CNRS’s Manouk Abkarian have directly visualized how speech and breath produce and expel droplets of saliva into the air.

RISK EXPERTS QUANTIFY RELIABILITY OF RENEWABLES, HELPING GRID OPERATORS AND SPURRING INVESTORS

Transitioning electricity grids to renewable energy means more solar and wind farms, but also new mathematical tools to plan around the intermittent nature of sun and wind, according to researchers recently awarded a $3.5-million grant from the U.S. Department of Energy to develop such tools.

"Everybody wants to move to renewables, but these technologies introduce new complications and uncertainties," said Ronnie Sircar, chair of Princeton's Department of Operations Research and Financial Engineering. Quantifying that uncertainty will not only help grid operators deploy renewables more efficiently, but will also allow the creation of financial tools, such as insurance products, that minimize risks and spur investments, Sircar said.

Conventional forecasting methods make it difficult for renewable energy suppliers to know exactly how much to charge for their electricity, and difficult for grid operators to choose what energy sources to buy. Other markets, such as stocks, oil, and housing, have well-established methods to quantify uncertainty. That allows investors to offer insurance that smooths out risks and encourages more investment.

"We are bringing financial thinking, risk quantification into this area," Sircar said.

Sircar and Rene Carmona, the Paul M. Wythes '55 Professor of Engineering and Finance, were among 11 research groups nationwide selected by the DOE to develop methods to manage risk and optimize markets for renewable energy.

The researchers are collaborating with the New York ISO, or independent system operator, which runs the electricity grid for New York state. A first step, said Sircar, will be to create and run simulations based on past data and tens of thousands of scenarios to determine the probability of many kinds of normal and rare events, including fluctuations in demand and prices.

"This is an enormous job because we are talking about the risk of the entire New York grid," Sircar said. "Once you have those metrics you can insure them, like insurance on your car or house. That is the overarching goal."

In addition to helping grid operators, electricity producers, and investors make decisions, the analysis could ultimately inform government policies designed to facilitate renewable energy, Sircar said.

– By Steven Schultz

A Princeton research team was among 11 research groups nationwide selected by the Energy Department to develop methods to manage risk and optimize markets for renewable energy.

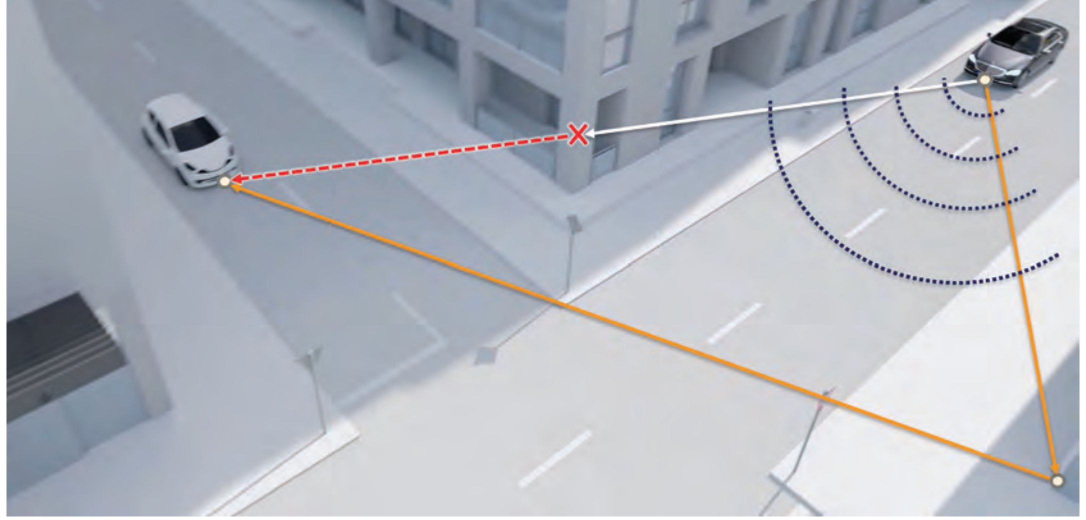


Image courtesy of the researchers

Researchers combined artificial intelligence and radar used to track speeders to develop a system that will allow vehicles to spot hazards hidden around corners.

NEW RADAR LETS CARS SPOT HAZARDS AROUND CORNERS

Using radar commonly deployed to track speeders and fastballs, researchers have developed an automated system that will allow cars to peer around corners and spot oncoming traffic and pedestrians.

The system, easily integrated into today's vehicles, uses Doppler radar to bounce radio waves off surfaces such as buildings and parked automobiles.

"This will enable cars to see occluded objects that today's lidar and camera sensors cannot record, for example, allowing a self-driving vehicle to see around a dangerous intersection," said Felix Heide, an assistant professor of computer science at Princeton University and one of researchers. "The radar sensors are also relatively low-cost, especially compared to lidar sensors, and scale to mass production."

In a paper presented at Conference on Computer Vision and Pattern Recognition, the researchers described how the system is able to distinguish objects including cars, bicyclists, and pedestrians, and gauge their direction and oncoming speed.

"The proposed approach allows for collision warning for pedestrians and cyclists in real-world autonomous driving scenarios — before seeing them with existing direct line-of-sight sensors," the authors wrote.

In recent years, engineers have developed a variety of sensor systems that allow cars to detect other objects on the road. Many of them rely on lidar or cameras using visible or near-infrared light, and such sensors preventing collisions are now common on modern cars. But optical sensing is difficult to use to spot items out of the car's line of sight. In earlier research, Heide's team has used light to see objects hidden around corners. But those efforts currently are not practical for use in cars because they require high-powered lasers and are restricted to short ranges.

In conducting that earlier research, Heide and his colleagues wondered whether it would be possible to create a system to detect hazards out of the car's line of sight using imaging radar instead of visible light. The signal loss at smooth surfaces is much lower for radar systems, and radar is a proven technology for tracking objects. The challenge is that radar's spatial resolution — used for picturing objects around corners such as cars and bikes — is relatively low. However, the researchers believed that they could create algorithms to interpret the radar data to allow the sensors to function.

"The algorithms that we developed are highly efficient and fit on current generation automotive hardware systems," Heide said. "So, you might see this technology already in the next generation of vehicles."

– By John Sullivan

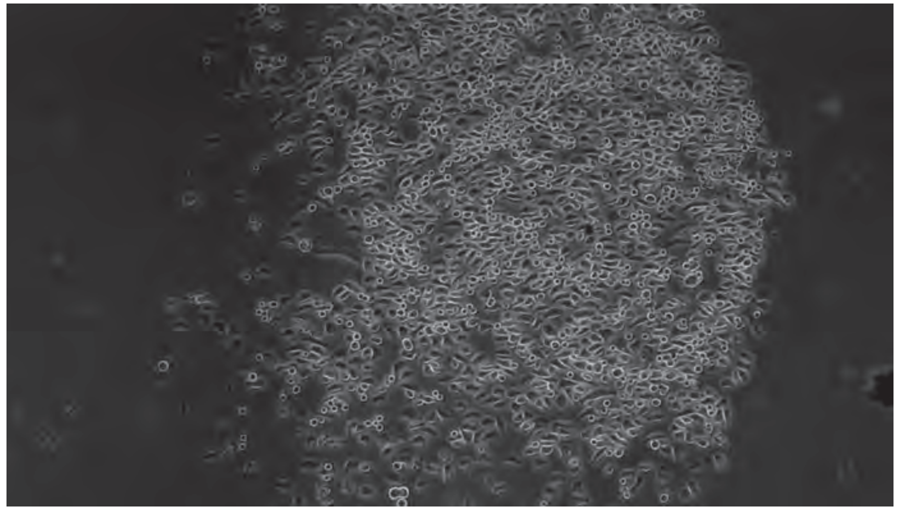
RESEARCHERS USE ELECTRIC FIELDS TO HERD CELLS LIKE FLOCKS OF SHEEP

Princeton researchers have created a device that herds cells like sheep by manipulating electric fields to mimic those found in the body during healing. The technique opens possibilities for tissue engineering, including approaches to promote healing, repair blood vessels, or sculpt tissues.

Scientists have long known that the body's electrochemical signals can influence the migration, growth, and development of cells — a phenomenon known as electrotaxis. These behaviors are not as well understood as chemotaxis, in which cells respond to chemical concentration differences. One barrier has been a lack of accessible tools to rigorously examine cells' responses to electric fields.

The new system, assembled from inexpensive and readily available parts, enables researchers to manipulate and measure cultured cells' movements in a reliable and repeatable way. In a paper in Cell Systems, the Princeton team described the assembly and preliminary studies using the device, which they call SCHEEPDOG, for Spatiotemporal Cellular HErding with Electrochemical Potentials to Dynamically Orient Galvanotaxis. (Galvanotaxis is another term for electrotaxis.)

Princeton researchers created a device that uses electrical fields to herd cells like sheep.



Video still courtesy of the researchers

Previous systems for studying cells' responses to electric fields have frequently been expensive and difficult to build, said co-lead author Tom Zajdel, a postdoctoral research fellow in mechanical and aerospace engineering. "We wanted to use rapid prototyping methods to make a well-defined device that you could just clamp onto your petri dish."

While there is a long history of work on electrotaxis, said Zajdel, the phenomenon is not well understood. Evidence shows, for example, that reversing the direction of a natural electric field can inhibit wound healing in animal models, while amplifying the existing field might improve healing.

"There are a lot of unknowns about how individual cells detect such fields," said senior author Daniel Cohen, an assistant professor of mechanical and aerospace engineering. "But the beauty of crowd dynamics is that even if you don't understand everything about the individuals, you can still engineer behaviors at the group level to achieve practical results."

The study "adds to the growing appreciation of cells' responses to bioelectric aspects of their environment," said Michael Levin, who directs the Center for Regenerative and Developmental Biology at Tufts University and was not involved in the research. "It demonstrates a technique to address not just individual cells' activities in response to bioelectric cues, but the action of a cell collective, which is essential to understand how physical forces play into the kind of cooperativity we see in embryogenesis, regeneration, and cancer." **– By Molly Sharlach**

CONTROLLING HEAT OPENS DOOR FOR NEXT-GENERATION LIGHTING AND DISPLAYS IN PEROVSKITE LEDS

Light-emitting diodes, or LEDs, are nearly ubiquitous in modern life, providing the brightness in phone displays, televisions, and lights. A new form of LEDs, made of a class of materials called halide perovskites, promises higher color quality and ease of manufacture, but has been known to fail when subjected to the kind of electrical current typically needed for practical uses. Now, Barry Rand, associate professor of electrical engineering and the Andlinger Center for Energy and the Environment, and a team of researchers have significantly improved the material's stability and performance by better managing the heat generated by the LEDs.

The research, published with co-lead author Claire Gmachl, the Eugene Higgins Professor of Electrical Engineering in Advanced Materials, identifies several techniques that reduce the accumulation of heat within the material, which extended its lifetime tenfold. When the researchers prevented the device from overheating, they were able to pump enough current into it to produce light hundreds of times more intense than a typical cell phone display. The intensity, measured in watts per square meter, reflects the real amount of light coming from a device, uninfluenced by human eyes or the color of the light. Previously, such a level of current would have caused the LED to fail.

The advance establishes a new brightness record and expands the limits of what's possible for the material by enhancing the well-established properties of perovskite LEDs and allowing those characteristics to be practically harnessed.

"It's the first time we've shown that heat appears to be the major bottleneck for these materials operating at high currents," said Rand. "This means the material could be used for bright lights and displays, which was never thought to be possible."

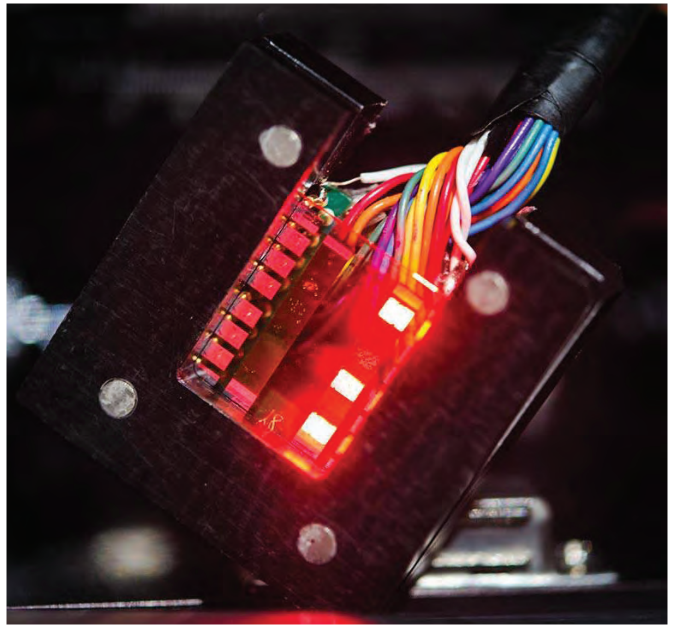


Photo by Sameer A. Khan/Fotobuddy

Princeton researchers have refined the manufacturing of light-emitting diodes (LEDs) made with crystalline structures known as perovskites, a more efficient and potentially lower-cost alternative to materials used in current LEDs

Rand said that clear pathways are now open for further development, but cautioned that the technology is still 10 to 20 years from wide-scale commercial use.

"This is a pretty major milestone," said Rand. "It's not only important to our research, but also for technologists, designers, and the electronics industry. We think there is a bright future for the material." **– By Molly Seltzer**

Photo by Mark Boss on Unsplash

St. Peter's Basilica in Rome, built by the Sangallo masters and consecrated in 1626, exhibits the double loxodrome technique

DOUBLE HELIX OF MASONRY — RESEARCHERS UNCOVER THE SECRET OF ITALIAN RENAISSANCE DOMES

What can modern engineering learn from an erstwhile jeweler who built the largest masonry dome in existence?

The Florentine duomo by Filippo Brunelleschi has been an engineering marvel for more than 500 years, showcasing ancient techniques that hold valuable insights for modern engineering. Until now, it has remained a mystery how the goldsmith and sculptor built the masterpiece, and how the masters who followed Brunelleschi carried on the tradition.

In a study published in Engineering Structures, researchers at Princeton University and the University of Bergamo revealed the engineering techniques behind self-supporting masonry domes inherent to the Italian renaissance. Researchers analyzed how cupolas like the duomo, part of the Cathedral of Santa Maria del Fiore in Florence, were built as self-supporting, without the use of shoring or forms typically required.

"Nothing is more moving," said Attilio Pizzigoni, co-author of the study, "than reading the lightness of the heavens in stone, in an absolute and simple form such as that of the Florentine cupola."

Sigrid Adriaenssens, professor of civil and environmental engineering at Princeton, collaborated on the analysis with graduate student Vittorio Paris and Pizzigoni, professor of engineering and applied sciences, both of the University of Bergamo. Their study is the first to quantitatively prove the physics at work in Italian renaissance domes and to explain the forces that allow such structures to have been built without formwork.

For Adriaenssens, the project advances two significant questions. "How can mankind construct such a large and beautiful structure without any formwork — mechanically, what's the innovation?" she asked. Secondly, "What can we learn?" Is there some "forgotten technology that we can use today?"

The computer analysis accounts for the forces at work down to the individual brick. The technique called discrete element modeling analyzed the structure at several layers and stages of construction. A limit state analysis determined the overall equilibrium state, or stability, of the completed structure. Not only do these tests verify the mechanics of the structures, but they also make it possible to recreate the techniques for modern construction.

The researchers said the results could be especially useful in cases where remote construction, by drone for example, could be done with minimal temporary supports.

"With these studies," said Pizzigoni, "we aim to approach moments in history when the sole form of technology available to man was the abstract rationality of geometry. […] What we as designers, architects, and builders can learn from the past is the knowledge of a structural equilibrium of form based on the geometry of materials and of their reciprocal measurements in three-dimensional space."

The specific structure that the team studied was Santa Maria, in Ciel d'Oro, of Montefiascone, Italy. The crux of their analysis rests on the geometrical pattern of bricks used throughout the interior dome, which appears to be the lynchpin vital in making the structure self-supporting. The bricks form a herringbone, a V-shaped pattern, between the horizontal field bricks and vertical bricks at the beginning and end of the horizontal rows. The arrangement creates lines of staggered vertical bricks that extend diagonally across the curvature of the dome.

The arrangement produced is a complex cross-herringbone spiraling pattern. One herringbone from both the left and right angles repeatedly cross each other, providing stability for the interior bricks and maintaining the dome's curvature. The researchers' analysis showed essentially that this is a double-helix of support that distributes and equalizes weight and thrust within the structure. This system of cross-herringbone veins is known as a double loxodrome.

The simple yet ingenious physics exhibited by the structure "is an elementary act that transforms the amorphous and inert material into a sign of life that [motivates] the tensions between opposing forces and composes them in their equilibrium," said Pizzigoni. Italian renaissance domes are an architectural form that "recognizes the disciplinary complexity" of blending the ideals of "stability, beauty, and utility, that runs between engineering, construction, and architecture.

– By Amelia Herb

An ancient Roman technique used in walls and hearths called opus spicatum, resembles the single loxodrome used by Brunelleschi in the Florentine duomo. Images: Opus spicatum, drawing of C. G. de Montauzan. Revolution dome and herring-bone spiralling pattern, drawing of F. C. Gurrieri.

Courtesy the researchers in collaboration with Lab-SABE, University of Bergamo

AMERICAN ACADEMY OF ARTS AND SCIENCES

Photos by David Kelly Crow and Nick Donnoli

From left: Ruby B. Lee, Margaret Martonosi, and Alexander Smits

Three professors at the School of Engineering and Applied Science have been named members of the American Academy of Arts and Sciences. The honorees, Ruby B. Lee, Margaret Martonosi, and Alexander Smits, are among 12 Princeton faculty members elected to the academy this year.

Ruby B. Lee, the Forrest G. Hamrick Professor of Engineering and a professor of electrical engineering, is a pioneer in computer architecture, hardware security, and multimedia. Her work at Princeton explores how the security and performance of computing systems can be significantly and simultaneously improved by hardware architecture. Her designs of secure processor architectures have strongly influenced industry security offerings and inspired new generations of academic researchers in hardware security, side-channel attacks and defenses, secure processors and caches, and enhanced cloud computing and smartphone security. Her research lies at the intersection of computer architecture, cybersecurity, and, more recently, the branch of artificial intelligence known as deep learning.

Margaret Martonosi, the Hugh Trumbull Adams ’35 Professor of Computer Science, specializes in computer architecture and computer hardware-software interface issues. She was one of the architects of the Wattch power modeling infrastructure, a tool that was among the first to allow computer scientists to incorporate power consumption into early-stage computer systems design. Her work helped demonstrate that power needs can help dictate the design of computing systems. More recently, Martonosi’s work has also focused on architecture and compiler issues in quantum computing. She currently leads the National Science Foundation’s Directorate for Computer and Information Science and Engineering, one of seven top-level divisions within the NSF.

Alexander Smits is the Eugene Higgins Professor of Mechanical and Aerospace Engineering (MAE), Emeritus, and a senior scholar in the department. His research focuses on fundamental issues in turbulence and fluid mechanics. Smits’ work has explored supersonic and hypersonic flows, bio-inspired flows, aerodynamics of sports, and novel energy-harvesting concepts. His studies on canonical wall-bounded turbulence included the introduction of unique facilities and novel instrumentation, and are considered a landmark achievement and the standard reference for many follow-up studies. Smits chaired Princeton’s MAE department for 13 years, and directed the Gas Dynamics Laboratory on the Forrestal Campus for 33 years. He has authored three books, including a highly recognized undergraduate fluid mechanics textbook. He has been awarded seven patents and helped found three companies. He transferred to emeritus status in 2018.

ENGINEERING PROFESSORS ELECTED TO NATIONAL ACADEMY OF SCIENCES

Two engineering faculty members, Jennifer Rexford ’91 and Elke Weber, have been elected as members of the National Academy of Sciences.

The academy’s class of 2020 includes 120 members and 26 international members recognized for their distinguished and continuing achievements in original research. Other Princeton faculty members elected to the academy this year are Anne Case, the Alexander Stewart 1886 Professor of Economics and Public Affairs, Emeritus; and Suzanne Staggs, the Henry Dewolf Smyth Professor of Physics.

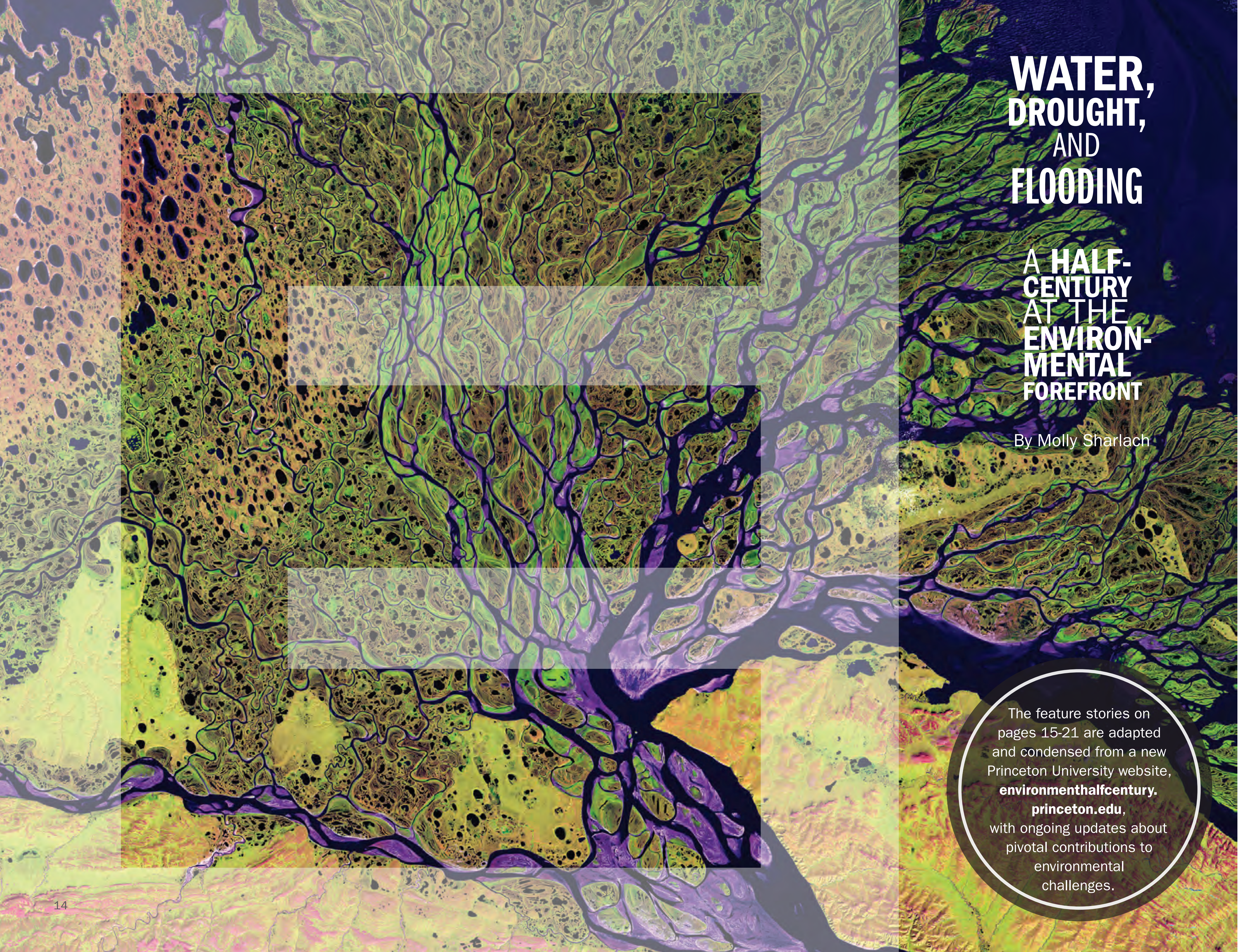
Rexford is the chair of the Department of Computer Science and the Gordon Y.S. Wu Professor of Engineering. A leader in computer networking, she has focused on methods to improve and expand digital communications. Among other areas, she has contributed to advances in the Border Gateway Protocol, which enables communications across the many networks that form the internet. She also helped establish methods to improve the design and control of networks at multiple levels. Rexford is also affiliated faculty in the Center for Information Technology Policy, Electrical Engineering, the Program in Applied & Computational Mathematics, the High Meadows Environmental Institute, and the Program in Gender and Sexuality Studies. In 2011, she received a Graduate Mentoring Award from Princeton’s McGraw Center for Teaching and Learning.

Weber is the Gerhard R. Andlinger Professor in Energy and the Environment and professor of psychology and public affairs at the Princeton School of Public and International Affairs. She is also the associate director for education at the Andlinger Center for Energy and the Environment.

Photos by David Kelly Crow

Jennifer Rexford and Elke Weber

Weber is known internationally for using behavioral decision science and psychological theory to advance global understanding of, and help to alleviate, social problems. She has been recognized for her distinctive approach to linking psychology principles to behavior change and uncovering the implications for environmental and economic policy, communications, management, economics, and leadership models. Her recent research shows how the personal carbon footprints of climate scientists, philanthropists, and other climate advocates affect the perceived legitimacy of and policy support for their climate strategies.



WATER, DROUGHT, AND FLOODING

A HALF-CENTURY AT THE ENVIRONMENTAL FOREFRONT

By Molly Sharlach

The feature stories on pages 15-21 are adapted and condensed from a new Princeton University website, **environmenthalfcentury.princeton.edu**, with ongoing updates about pivotal contributions to environmental challenges.

Satellite photo of the Lena Delta Reserve in Russia by USGS EROS Data Center Satellite Systems Branch, courtesy of NASA

Life is governed by water. Rainfall brings plenty, but floods and drought are destructive. When it comes to preserving this precious resource and the balance between too little and too much, Ignacio Rodriguez-Iturbe thinks humanity could learn a lot from plants.

"They don't know when the rain will arrive, and they don't know how much rain will come," he said. Yet plants are attuned to their environment and work within the ecosystem to make the most of what water there is. "That's the life of plants, and they survive."

Rodriguez-Iturbe, the James S. McDonnell Distinguished University Professor of Civil and Environmental Engineering, Emeritus, is among the founders of ecohydrology, a discipline that examines the roles of landscapes, plants and soil in the water cycle. A professor at Princeton for 17 years, in 2002 he won the Stockholm Water Prize, known informally as the "Nobel Prize of water."

He is one of several faculty members who have built a substantial record at Princeton for understanding and addressing critical problems involving water. Their tools and discoveries contribute to cleaning up watersheds and inform policies to plan for water scarcity and flooding around the globe.

Professor emeritus Eric Wood has pioneered computational models to track the impacts of climate change on drought and flood patterns — work that earned him the 2017 Robert E. Horton Medal for outstanding contributions to hydrology from the American Geophysical Union. Peter Jaffé, the William L. Knapp '47 Professor of Civil Engineering, has developed methods for cleaning intractable pollutants from groundwater and wetlands.

Photo by Laura Pedrick

Ignacio Rodriguez-Iturbe

Conservation, agriculture, and public health

To understand how water moves through living systems, Rodriguez-Iturbe and his colleagues in engineering, geosciences and ecology and

Photo by Brian Wilson

Simon Levin

evolutionary biology developed mathematical approaches integrating rainfall data with information on geological features, soil moisture, and vegetation.

Rodriguez-Iturbe, now at Texas A&M University, continues to collaborate with Simon Levin, Princeton's James S. McDonnell Distinguished University Professor in Ecology and Evolutionary Biology. In 2019, they published an analysis of tree cluster patterns in African savannas, which have been challenging to explain in mathematical terms. The study explained the tree clusters' dependence on local soil moisture and developed a model to help conservation efforts that accounts for impacts of fires and wildlife on trees.

The work, combining water dynamics and ecology, is a good example of Princeton's approach, which begins with a wide view and narrows to detailed solutions.

Photo by Denise Applewhite

Peter Jaffé

"The beauty of the work that's been done here in ecohydrology is that it takes the random nature of rainfall and integrates it into a model where you can actually find solutions in a way that is absolutely elegant in terms of its mathematics, and still is driven by really practical questions," said Michael Celia *83, the Theodora Shelton Pitney Professor of Environmental Studies and director of the High Meadows Environmental Institute, who has also collaborated with Rodriguez-Iturbe.

Another collaborator, Amilcare Porporato, worked with Rodriguez-Iturbe as a visiting scholar at Princeton from 1999 to 2001 and is now the Thomas J. Wu '94 Professor of Civil and Environmental Engineering. In work supported by Princeton's Carbon Mitigation Initiative, Porporato works with colleagues in engineering and geosciences to investigate how plants and soils sequester carbon. In addition to improving soil carbon information in climate models, their results could guide agricultural and conservation strategies to help curb climate change. He also develops predictive frameworks that integrate rainfall fluctuations with agricultural outputs and patterns of disease, including a collaborative study on dengue fever outbreaks supported by the High Meadows Environmental Institute's Climate Change and Infectious Disease initiative.

Photo by Isometric Studios

Amilcare Porporato

Mapping drought risks

Enabling reliable, sustainable agriculture under water scarcity has been a priority for Eric Wood, the Susan Dod Brown Professor of Civil and Environmental Engineering, Emeritus, who joined Princeton's faculty in 1976. Wood helped establish the use of satellite data in hydrology and improved the representation of the water cycle in climate models, including the energy implications of water interacting with different land types.

"The work that Eric pioneered is what is called the assimilation approach, which is basically bringing many streams of useful but independent data together in a consistent fashion. Once you have that, then you can start to understand how the water cycle varies, you can do prediction of droughts and floods, you can look at future climate impacts," said Justin Sheffield, who has worked closely with Wood for two decades, first as a research scholar at Princeton and now as a professor at the University of Southampton in the U.K. In 2008, Wood, Sheffield and colleagues launched the African Flood and Drought Monitor, developed with support from the United Nations Educational, Scientific and Cultural Organization (UNESCO). Since much of sub-Saharan Africa's farming depends on rain, drought forecasts can provide critical information for farmers and policymakers. The monitor complements ground-based information with satellite data and hydrological modeling, and uses state-of-the-art prediction tools to generate seasonal forecasts.

Photo by David Crow Kelly

Eric Wood

Resilience to future floods

Better data sets and predictive tools have also deepened understanding of extreme storms and flooding, a major focus for James Smith, the William and Edna Macaleer Professor of Engineering and Applied Science, and Ning Lin, associate professor of civil and environmental engineering.

Smith, who joined Princeton in 1990, helped establish a radar network that has since become a principal tool for U.S. weather forecasting and measuring rainfall.

Thanks to this groundwork, Smith was well-positioned for a watershed study on a catastrophic flood along the Rapidan River in Virginia's Blue Ridge Mountains, following a storm that dumped more than 25 inches of rain in 6 hours on June 27, 1995.

Such extreme events, the study showed, reveal the limits of the theory that forests can prevent flooding. Smith's group has since extended this research to examine how complex terrain can create hot spots of extreme rainfall — including the influences of urban infrastructure on local climate, rainfall and flooding.

Photo by Sameer A. Khan/Fotobuddy

James Smith

In collaboration with Smith and other colleagues, Ning Lin's work aims to make coastal communities more resilient to storms and flooding.

"Our research combines the state of the science — our current understanding of hurricanes, the climate system, infrastructure systems, and the coastal environment — to project the impact of climate change on hurricanes and risks to coastal areas," said Lin. "Then we link that to the development of mitigation strategies, both in engineering and in policy and economic perspectives."

Photo by David Crow Kelly

Ning Lin

In 2019, Lin and colleagues published detailed projections of hurricane flood hazards for counties along the U.S. Atlantic and Gulf coasts at the end of this century, showing that current 100-year floods will likely occur every 30 years. This type of high-resolution risk mapping is critical to making informed policies, said Lin.

Lin is one of several Princeton researchers involved in Structures of Coastal Resilience, a project that combines flood predictions with infrastructure improvements such as storm surge barriers that double as parks. Along with Guy Nordenson, professor of architecture and affiliated member of the Department of Civil and Environmental Engineering, and Michael Oppenheimer, the Albert G. Milbank Professor of Geosciences and International Affairs and the High Meadows Environmental Institute, Lin has also served on the New York City Panel on Climate Change. The panel is working to make New York a leader in advancing flexible solutions to coastal protection based on scientific projections of future hazards.

In the field of ecohydrology, Rodriguez-Iturbe is also looking to coastal areas as a new frontier — he's interested in the complex dynamics of waves, dunes and vegetation.

"Coastal ecosystems are extremely important for humankind now and in the future, and we need to know more about the core science of how these ecosystems respond under different conditions," he said. **E**

TOUGH, TIMELY, AND TEAM-DRIVEN

50 YEARS OF ENERGY RESEARCH

By Molly A. Seltzer

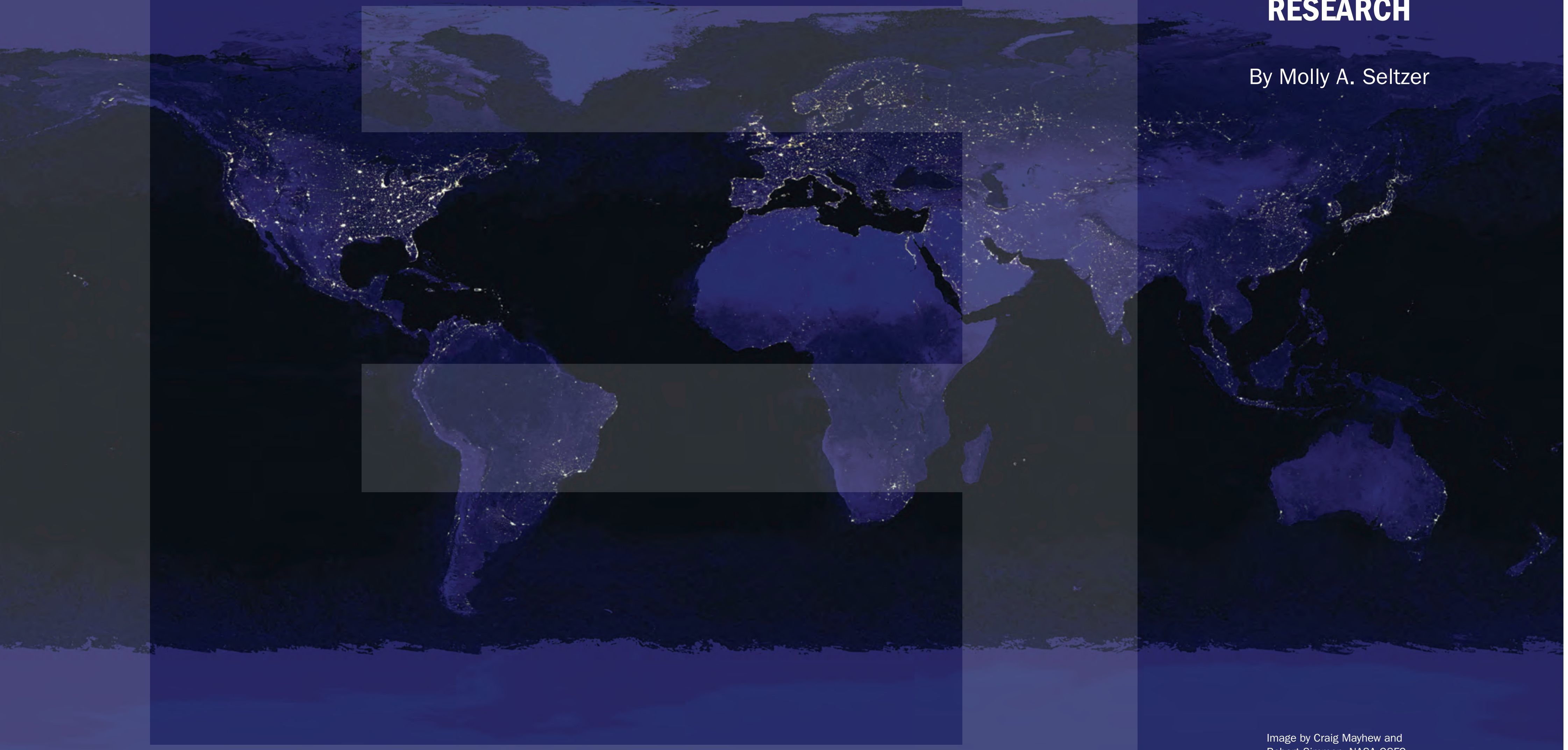


Image by Craig Mayhew and Robert Simmon, NASA GSFC. Image from NASA's Visible Earth series

Yueh-Lin (Lynn) Loo *01 had a moment of clarity while sitting at a long wooden conference table at Princeton University's Maeder Hall Auditorium. The director of the Andlinger Center for Energy and the Environment was meeting with colleagues from engineering, political science, psychology, and economics to discuss a massive problem: how to provide energy to the world while eliminating greenhouse gas emissions.

Photo by David Kelly Crow

Yueh-Lin (Lynn) Loo '01

"I got goosebumps along the back of my neck," said Loo, the Theodora D. '78 and William H. Walton III '74 Professor in Engineering and a professor of chemical and biological engineering. "Seeing so many experts at the table, many of whom had never worked on energy before, showed me that we had built something whose sum was greater than the individual parts."

The scene took place in June 2019 at the inaugural workshop of Rapid Switch, an international research collaboration spearheaded by the Andlinger Center and aimed at global decarbonization in all regions and economic sectors.

The threads of energy and environmental research

Fifty years before the Maeder Hall meeting, in 1969, University researchers forged a similar collaboration. A wave of energy and environmental problems came to bear in the United States, from the Cuyahoga River fire to the Santa Barbara oil well blowout. Universities grappled with how to respond.

Princeton University President Robert F. Goheen '40 spotted a young physicist, an assistant professor at Yale University, with an interest in environmental issues. The professor had just published a book, "Patient Earth," and was looking to move from the abstract realm of physics to research that would more directly protect the planet. Goheen recruited Robert H. Socolow to build a multidisciplinary research program on energy and the environment, the University's first.

"Princeton's offer could not have been more exciting to me; building an interdisciplinary center was exactly what I wanted to do," said Socolow. What became the Center for Energy and Environmental Studies (CEES) was founded in 1971 and housed in the School of Engineering and Applied Science.

Photo by Bumper deJesus

Robert Socolow

Socolow said the University's response to environmental issues was "unusually robust." He said other Ivy League schools were not investing in a tenure-track professors with an environmental mission.

During its 20-year span, CEES responded to national issues and provided meaningful, timely research. With increased interest in conservation and nuclear power after the 1973 oil crisis, the researchers made recommendations on nuclear security, and demonstrated the economic and environmental benefits of cogeneration in power plants. The center's research paved the way for the passage of the Public Utilities Regulatory Policies Act, which promoted energy conservation and deregulated the electric industry in favor of competition among electric producers.

Photo courtesy of PPPL

Lyman Spitzer

The power within the sun

During the same period, Princeton University became a leader in nuclear fusion, the energy source that powers stars, including the sun. In 1951, Princeton astrophysicist Lyman Spitzer met with the Atomic Energy Commission and proposed a method for controlled fusion on Earth. Realizing that fusion could become an inexhaustible energy source, the Commission greenlighted the project. After being declassified in 1958, the program became Princeton Plasma Physics Laboratory, a U.S. national lab managed by Princeton University.

"Princeton's always been the leader in the world. Princeton Plasma Physics Laboratory is the most famous lab in fusion and has been since it was declassified in 1958," said Steven Cowley '85, director of the Princeton Plasma Physics Laboratory (PPPL) and former chief executive of the United Kingdom Atomic Energy Authority. The lab's Tokamak Fusion Test Reactor was first to produce substantial amounts of fusion energy, generating a burst of roughly 10 million watts of power in 1994. The Laboratory followed this with new generations of test reactors, and is collaborating on the world's most advanced fusion reactor now under construction in Europe, the International Thermonuclear Experimental Reactor.

The climate age

In the late 20th century, scientists tracking environmental problems shifted to greenhouse gases. Fears about fossil fuel shortages, nuclear accidents, and air and water pollution were slowly overtaken by concerns about climate change.

"We were beginning to understand that small human activities could overwhelm the Earth," said Socolow.

Robert Williams, founder of CEES's Energy Systems Analysis Group, was working on ways to manage carbon in the atmosphere when BP called upon the academic community for support.

Williams recognized that carbon dioxide could be removed from the flues of power plants and stored instead of being released into the atmosphere. The proposal offered a bridge between energy sources currently driving the economy and future renewable power. Geologists found potential for adequate storage underground, which is regarded as a safer than ocean storage. The team, including a range of engineers and ecologists, submitted a research proposal to BP.

Photo courtesy of PPPL

Steven Cowley '85

"Very few people at Princeton thought we could beat Stanford and MIT," said Socolow. "But we did, and it was because we presented ourselves as looking at a whole environmental problem, not at narrow parts of it."

BP awarded the multimillion-dollar grant to Princeton, which established the Carbon Mitigation Initiative in 2000 as part of High Meadows Environmental Institute.

A new movement

In 2007, the Intergovernmental Panel on Climate Change issued its fourth assessment report, which presented the scientific consensus around climate change and pointed to human activity as the cause.

Photo courtesy of the Andlinger Center for Energy and the Environment

Robert Williams

The report "convinced me that human beings are having a profound effect on the climate," said Emily Carter, a Princeton professor of mechanical and aerospace engineering and applied and computational mathematics at the time. Carter shifted her research to focus on sustainable energy.

The University leadership also saw the need for greater contribution to the pressing issues of energy and climate as it had done for the environment more than a decade before with the recently renamed as the High Meadows Environmental Institute. Shirley M. Tilghman, then the University president, said she knew the response "had to be dramatic and significant."

"If we were a serious research university in the 21st century, we had to have a strong presence in the field of energy research," said Tilghman.

Photo by David Kelly Crow

Emily Carter

Tilghman found support from Gerry Andlinger, a 1952 alumnus who donated $100 million to establish the Andlinger Center for Energy and the Environment. Carter became the founding director.

Carter charged ahead with the vision of a university center developing not just technical solutions, but also those based on policy and human behavior. She sought participation from every relevant department through grants, partnerships, and recruitment. The Andlinger Center brought in new joint-appointed faculty members who worked on solutions ranging from low-carbon cements to technologies for improved power delivery to frameworks for environmental decision-making.

Loo, the associate director, succeeded Carter, who became engineering dean and later provost at UCLA. As associate director, Loo had founded the center's corporate partner program, Princeton E-ffiliates Partnership, and as director she focused on external engagement and high-impact projects. Incorporating the Energy Systems Analysis Group into the center, Loo challenged researchers to identify pathways to decarbonization that are feasible and effective worldwide, including areas with growing populations and limited power access. Loo also led the center's creation of the University's first executive education program aimed at equipping young global leaders to guide their organizations to think critically and creatively about their roles in solving environmental and climate problems.

Five decades after Socolow's initiative helped lay the foundations for modern environmental research and a decade since the Andlinger Center's establishment, Loo takes pride in the community the Andlinger Center has built.

No individual research group, or even a whole institution, will have all the expertise to solve the complex challenges, "but what I can do is bring people together," said Loo. **E**

RECENT FACULTY AWARDS, PROMOTIONS, AND HONORS


Photo by Tori Repp/Fotobuddy
Celeste Nelson


Photo by Frank Wojciechowski
Mona Singh


Photo by Frank Wojciechowski
Michael Freedman

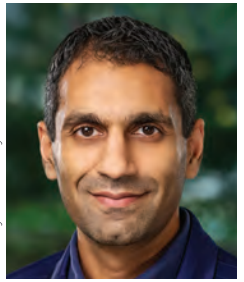


Photo by David Kelly Crow
Naveen Verma

CHEMICAL AND BIOLOGICAL ENGINEERING

Clifford Brangwynne
Blavatnik National Award Laureate
Wiley Prize in Biomedical Sciences

Sujit Datta
35 Under 35, American Institute of Chemical Engineers
Innovative Early-career Engineer, National Academy of Engineering
Unilever Award, American Chemical Society
CAREER Award, National Science Foundation

Yueh Lin (Lynn) Loo *01
Fellow, Materials Research Society

Celeste Nelson
Pomeroy and Betty Perry Smith Professor of Chemical and Biological Engineering

Rodney Priestley
Young Investigator Award, American Chemical Society

William Schowalter
Honorary Degree, Princeton University

Sankaran Sundaresan
Distinguished Professor in the Department of Chemical Engineering, Indian Institute of Technology, Madras

CIVIL AND ENVIRONMENTAL ENGINEERING

Ian Bourg
Howard B. Wentz, Jr. Junior Faculty Award, SEAS

Amilcare Porporato
Dalton Award, European Geophysical Union

Zhiyong "Jason" Ren
Walter L. Huber Civil Engineering Research Prize, American Society of Civil Engineers

COMPUTER SCIENCE

Jia Deng
E. Lawrence Keyes, Jr./Emerson Electric Co. Faculty Advancement Award, SEAS
CAREER Award, National Science Foundation

Michael Freedman
Fellow, Association of Computing Machinery

Zachary Kincaid
Howard B. Wentz, Jr. Junior Faculty Award, SEAS
CAREER Award, National Science Foundation

Szymon Rusinkiewicz
David M. Siegel '83 Professor of Computer Science

Olga Russakovsky
Emerging Leader Abie Award in Honor of Denice Denton, AnitaB.org
Anita Borg Early Career Award, Computing Research Association

Mona Singh
Fellow, Association of Computing Machinery

Matthew Weinberg
Research Fellow, Alfred P. Sloan Foundation
CAREER Award, National Science Foundation

ELECTRICAL ENGINEERING

Yuxin Chen
Young Investigator Program Award, U.S. Army Research Office


Photo by Sameer A. Khan/Fotobuddy
Zhiyong "Jason" Ren

Andrea Goldsmith
IEEE Leon K. Kirchmayer Graduate Teaching Award
Marconi Prize, Marconi Society

H. Vincent Poor *77
Corresponding Member, Heidelberg Academy of Sciences

Jeffrey Thompson
E. Lawrence Keyes, Jr./Emerson Electric Co. Faculty Advancement Award, SEAS

Naveen Verma
Director, Keller Center for Innovation in Engineering Education

MECHANICAL AND AEROSPACE ENGINEERING

Egemen Kolemen
David J. Rose Excellence in Fusion Engineering Award, Fusion Power Associates

Naomi Leonard '85
John R. Ragazzini Education Award, American Automatic Control Council

Anirudha Majumdar
Google Faculty Research Award
Amazon Research Award
Alfred Rheinstein Award, SEAS

Michael Mueller
Research Excellence Award, The Combustion Institute
Editorial Board Member, Combustion and Flame

OPERATIONS AND FINANCIAL ENGINEERING

René Carmona
Joseph L. Doob Prize, American Mathematical Association

Miklos Racz
Howard B. Wentz, Jr. Junior Faculty Award, SEAS

Ronnie Sircar
Fellow, Society for Industrial and Applied Mathematics

FACULTY HONORED FOR EXCELLENCE IN TEACHING AND MENTORING


Photo by David Kelly Crow
Athanassios Panagiotopoulos

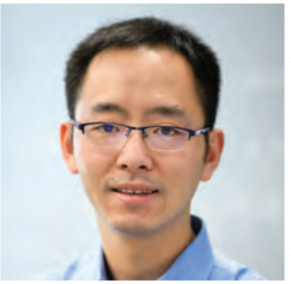


Photo by Sameer A. Khan/Fotobuddy
Yuxin Chen


Photo by David Kelly Crow
Wyatt Lloyd

Athanassios Panagiotopoulos, the Susan Dod Brown Professor of Chemical and Biological Engineering and chair of chemical and biological engineering, received the 2020 distinguished teacher award from the School of Engineering and Applied Science. Panagiotopoulos' research team develops and applies simulation techniques for studying the properties of fluids and materials. A member of the National Academy of Engineering, he is the author of a standard text on thermodynamics.

Antoine Kahn *78, vice dean of engineering, announced the award during the 2020 Class Day ceremony, adding that it "recognizes a sustained record of excellence in teaching and in making contributions to our educational mission."

Kahn said students praised Panagiotopoulos' mastery of the underlying concepts of his discipline and his ability to explain difficult ideas in an approachable fashion.

"Other courses often forget to address why scientists have created coefficients and quantities; Thanos was able to tell us the reasoning behind them," Kahn said, quoting one student. He added that another called Panagiotopoulos' textbook straightforward, concise, illustrative, useful, and cool. "And for all of you who have ever tried to understand thermodynamics, you certainly understand the value of such a compliment."

Yuxin Chen, assistant professor of electrical engineering, was one of four recipients of the Graduate Mentoring Award from the McGraw Center for Teaching and Learning. Chen studies the mathematical foundations of data science, optimization, high-dimensional statistics, statistical learning, and information theory; and their applications to medical imaging and computational biology.

Students said they appreciated Chen's thorough explanations of complex materials and his constructive feedback. "Even if he is busy, he is always willing to discuss ideas or proof details with me for hours, which is always fruitful," said an advisee. Chen also serves as an exceptional role model. "Perhaps the most important thing I learned from him is not about the algorithms and proofs, but the philosophy of the academic life," said a student. "From him, I see what the life of an enthusiastic and self-disciplined scholar would be."

Wyatt Lloyd, assistant professor of computer science, was one of two faculty members to receive the annual award for excellence in undergraduate teaching from the Princeton University chapter of the Phi Beta Kappa honor society. Lloyd, who received his Ph.D. from Princeton in 2013, studies the theory, design, implementation, evaluation, and deployment of large-scale distributed systems.

Senior Audrey Cheng, a student in Lloyd's distributed systems class, said that "even in a 90-person room, he had a manner of engaging with students that allowed him to explain technical details with ease." She noted that Lloyd "recognized the challenges of this course and provided an abundance of support."

"His kind encouragement has helped increase my confidence in my abilities as a researcher and has motivated me to passionately tackle research questions," she said.

Award recipients were recognized during an online Class Day ceremony.

CLASS DAY RECOGNIZES CLASS OF 2020 FOR INNOVATION AND DETERMINATION

H. Vincent Poor, then interim dean of engineering, congratulated graduates in a virtual Class Day ceremony on June 1. With 334 graduates in engineering and computer science (A.B.), members of the Engineering Class of 2020 played intercollegiate athletics, developed novel technologies, served their community, and created art and music, Poor said. Graduates will further their education at top programs at Stanford, Cambridge, Caltech, and Carnegie Mellon; others will work for employers including Merck, Google, Nvidia, and Lockheed Martin; while others will attend law school, medical school, or serve in the military.

The major award winners at the 2020 Princeton Engineering Class Day, as presented by Associate Dean for Undergraduate Affairs Peter Bogucki, were:

J. Rich Steers Award
Jeb Banavige
Mechanical and Aerospace Engineering
Kara Dowling
Operations Research and Financial Engineering

Jeffrey O. Kephart ’80 Prize In Engineering Physics
Geoffrey Zheng
Physics

Joseph Clifton Elgin Prize
Adam Chang
Operations Research and Financial Engineering
Yolanda Jin
Civil and Environmental Engineering

David Major
Computer Science

George J. Mueller Award
Margaret O’Connell
Chemical and Biological Engineering
Andrew Griffin
Computer Science

Calvin Dodd MacCracken Senior Thesis/Project Award
Sofia Bisogno
Civil and Environmental Engineering
Markos Markakis
Electrical Engineering
Alice Xue
Civil and Environmental Engineering

The Tau Beta Pi Prize
Nina Arcot
Mechanical and Aerospace Engineering
Meghan Slattery
Operations Research and Financial Engineering

The Lore Von Jaskowsky Memorial Prize
Clare Cook
Electrical Engineering
Audrey Shih
Chemical and Biological Engineering

James Hayes-Edgar Palmer Prize In Engineering
Nicholas Johnson
Operations Research and Financial Engineering

NICHOLAS JOHNSON NAMED VALEDICTORIAN, A FIRST FOR OPERATIONS RESEARCH AND FINANCIAL ENGINEERING

In an episode of Princeton’s “We Roar” podcast, Nicholas Johnson reflected on his experiences and shared his pride at becoming the first Black student to be named valedictorian in University history.

“I think to my parents and my grandparents, and all of the many influential Black and African American individuals I’ve had in my life who’ve encouraged me to be my best self, be my truest self, not feel obliged to conform to the expectations that the world has of me, and feel a certain confidence in carving my own path,” said Johnson, the 2020 valedictorian. “And that guidance, those words, have truly pushed me over my time at Princeton.”

Johnson, an operations research and financial engineering concentrator from Montreal, was announced as valedictorian in April with Latin salutatorian Grace Sommers. He spoke at Princeton’s virtual Commencement on May 31.

Johnson expressed empathy for his 2020 classmates, whose studies and celebrations were disrupted by the COVID-19 pandemic.

“The pandemic has impacted us, impacted myself, impacted my classmates, very significantly, in unprecedented ways,” he said. “Working from home to finish off our Princeton experience poses a unique set of challenges, particularly for students who don’t have a supportive home environment or one that is not conducive to conducting Princeton’s academic work. My heart especially goes out to all students who have lost loved ones to the pandemic.”

Preparing to graduate during the pandemic is challenging, Johnson said, and this will be a defining moment for the Class of 2020.

“Life can be viewed as a series of challenges,” he said. “And an individual’s life and an individual’s legacy are often defined by how they respond to those challenges, how they respond to these difficult times.”

Johnson called his Princeton experience “transformative.” He said he hopes to develop theory that unifies optimization and machine learning, and to contribute to building innovative, analytics-based organizations. He also is interested in developing technology policy designed to ensure that algorithmic advances occur equitably and work toward decreasing existing inequalities, rather than creating new ones or exacerbating existing ones.

As he said farewell to Princeton, Johnson recalled the many things that made his experience so meaningful, including friends, mentors, and international travel experiences that allowed him to immerse himself in other cultures.

“I’ve had many of my views challenged,” he said. “And I think that coming out of Princeton, I have grown a significant amount. … I’m very grateful for Princeton.”**– By Denise Valenti**

Photo by Lisa Festa, Center for Career Development

Nicholas Johnson

THESIS PROBES INTRICACIES OF GROUNDWATER CLEANUP

Audrey Shih investigated how specialized materials act to remove pollutants from the porous rock of groundwater aquifers. In this photo from summer 2019, Shih preps a small plastic apparatus containing material that simulates a porous rock environment. Graduate student Christopher Browne, behind, provides guidance. Shih's 2019 summer research in Sujit Datta's laboratory was supported by the Andlinger Center for Energy and the Environment.

Photo by Bumper DeJesus

Audrey Shih entered Princeton with aspirations of using science to protect vulnerable people from allergens. "I have a severe peanut allergy, and I thought I might help come up with a method to detect allergens in food," said Shih.

After declaring her concentration in chemical and biological engineering (CBE) and beginning her coursework in the department, "my interest shifted more toward materials science and the more physical than biological side of CBE," she said.

An email to Sujit Datta, an assistant professor in the department, launched Shih on a two-year-long research project to help thwart a different type of chemical threat: pollutants like crude oil and mercury that can linger in groundwater even after major cleanup efforts. In Datta's lab, she investigated how specialized materials act to remove recalcitrant pollutants.

Shih, a member of the Class of 2020, finished writing her senior thesis on the topic from her family's home in Columbus, Ohio, after the University halted on-campus instruction and research activities in response to the COVID-19 pandemic. In recognition of her thesis work, Shih was one of two graduating seniors presented with the engineering school's Lore von Jaskowsky Memorial Prize for Contributions to Research during Class Day celebrations on June 1. Shih, who completed a certificate in materials science and engineering in addition to her CBE concentration, also received an outstanding senior thesis award from the Princeton Institute for the Science and Technology of Materials.

"It's been harder to stay motivated and focused" at home, said Shih. "There were times when I wished that I could be in Firestone Library to work on my thesis." She and a few friends tried using Zoom video conferencing to recreate the experience of writing at the same table — "just having each other on the call without really talking. But everyone's in different time zones, so it was a little bit difficult," she said.

Shih's thesis focused on specially formulated chain-like molecules called polymers that can help flush contaminants from hard-to-reach crevices in underground aquifers. How these polymers move through porous rocks to dislodge pollutants — and why they are more effective in some settings than in others — is not well understood.

"Polymer solutions behave unlike most fluids. They have an elastic component to them in addition to being quite viscous, and when they go through porous spaces, weird things happen," said Shih. "A lot of strain builds up as they're trying to get through these little holes, and they form interesting flow structures." **– By Molly Sharlach**

THESIS EXPLORES REGIONAL BENEFITS OF CLEANER AIR IN CHINA

After months researching China's notorious air pollution for her senior thesis, Naomi Cohen-Shields stepped off a plane in Beijing in December 2019 to a shockingly clear sky. Her gaze fell across the unencumbered skyline of the city where the term "airpocalypse" had been coined in 2013 to describe the thick, toxic smog that enveloped China's capital.

What Cohen-Shields — who received her bachelor's degree June 2 in civil and environmental engineering — didn't know was that wind and periodic snowstorms whisk away the smoke and exhaust. But these were exactly the kinds of details she went to China to look for.

For her thesis, Cohen-Shields analyzed the effectiveness of China's efforts since 2013 to reduce air pollution and its toll on public health and the economy. She also wanted to investigate how air pollution differs across China's 22 provinces based on regional affluence — and if its poor and rural populations bear a larger share of the burden. Working with thesis adviser Denise Mauzerall, professor of civil and environmental engineering and public and international affairs, Cohen-Shields found dramatic progress, but the largest improvements have occurred in wealthier northern regions where air pollution has historically been highest.

"The air quality is still generally poor across China, but it has improved markedly," Cohen-Shields said. "We've seen a lot of success across the board, but there's been more success in reducing pollution in major metropolises known for having high levels of pollution and obviously are also areas of concentrated wealth."

Cohen-Shields' work — supported in part by senior thesis funding from the High Meadows Environmental Institute — took her to four cities in China where she experienced the geographic and political factors that influence air quality, met university researchers who study it, and talked with the people whose everyday actions make a difference.

"It exposed me to a lot of the different factors that need to be considered in any sort of analysis of air pollution policy," said Cohen-Shields, who earned certificates in environmental studies and values and public life. "Numbers don't necessarily add enough depth to what makes that transition hard. It was important to talk to the people who live through the reality I was trying to describe through numbers and research."

She received an Environmental Studies Book Prize in Environmental Engineering for her thesis during the Program in Environmental Studies Class Day ceremony May 29.
– By Morgan Kelly

Naomi Cohen-Shields of Princeton's Class of 2020 analyzed the effectiveness of China's efforts to reduce air pollution for her senior thesis research. She also investigated how air pollution differs across China's provinces based on regional affluence — and if poor populations face more exposure. Cohen-Shields is pictured at the Great Wall of China in December 2019.

Photo courtesy of Naomi Cohen-Sheilds

ANASTASIA BIZYAEVA

Ph.D. Candidate, MECHANICAL AND AEROSPACE ENGINEERING

“I’m glad to be a Princeton engineer because it lets me be creative in an interdisciplinary work space."

As a member of Professor Naomi Leonard’s Dynamical Control Systems Lab, Bizyaeva creates models and algorithms of group opinion dynamics, which are inspired by collective behaviors of natural systems, like groups of animals and groups of interconnected neurons.

Bizyaeva sits with two of the robots that test decision making programs based on her mathematical models and algorithms of group opinion dynamics.

All photos courtesy of the students

These models can be useful for programming robot teams to perform jobs such as search-and-rescue missions, where the individual robots must act collectively as they react to emerging situations. She also participates in interdisciplinary collaborations, including one with scientists at the Princeton Neuroscience Institute, which looks at ways of understanding human cognition from a mathematical, dynamical systems approach.

One of the most interesting things to her about her work is seeing how universal certain ideas are. She said that studying collective behaviors in animals and neurons translates to thinking about social groups and "to control protocols that I design, which are meant for artificial systems, like robots, or smart cars or whatever it may be down the line, who knows?”

“The universality of the mathematical tools we use to describe very different systems really stands out to me because it's kind of beautiful, seeing connections between very unexpected things that are quite similar in principle,” she said.

TOM POSTMA

Ph.D. Candidate, CIVIL AND ENVIRONMENTAL ENGINEERING

“I’m a Princeton engineer because technology and innovation are key to solving global problems.”

If we are to achieve the main goal of the Paris Climate Agreement and keep global temperature rise from preindustrial levels below 2 degrees Celsius, humanity has a finite budget of carbon dioxide that it can safely emit. One method of controlling the amount of CO_2 released to the atmosphere is harvesting large quantities from industrial sources and injecting it into deep underground rock formations, such as saline aquifers, a process known as carbon capture and storage.

Postma is a graduate coach for Princeton’s men’s heavyweight crew

As a fourth-year graduate student and part of the Carbon Mitigation Initiative within the High Meadows Environmental Institute, Postma is developing computer models to describe what happens to the injected CO_2 over time, a process that requires a combination of fluid mechanics, chemistry, thermodynamics, and geology. Once finished, these models can be used to assess whether the injected CO_2 will remain securely stored over long periods of time without unintended migration to surrounding formations or to the surface.

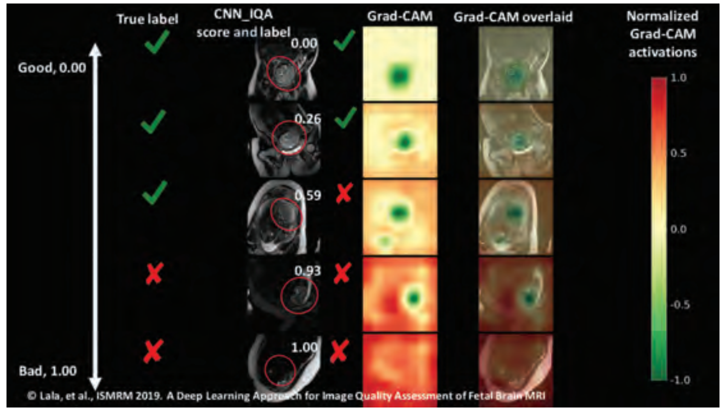
SAYERI LALA

Ph.D. Candidate, ELECTRICAL ENGINEERING

“I’m a Princeton engineer because the Princeton engineering community is rich with opportunities for interdisciplinary collaboration.”

A second-year student, Sayeri works at the intersection of signal processing and machine learning. In her previous research, she studied methods to improve the quality of fetal brain MRI scans. Because fetuses are constantly moving, scans might be degraded by motion artifacts, impairing their readability. Also, these evaluations are complicated by the fact that fetal brains can be in any stage of development.

To help radiologists better assess if a fetus is at increased risk for neurodevelopmental disabilities, she trained a convolutional neural network, a type of artificial intelligence algorithm, to automatically assess and improve the quality of fetal brain MRI scans.



Detection of fetal brains in MRI scans

GRADUATE STUDENTS HONORED FOR OUTSTANDING TEACHING

Two engineering graduate students were among seven recipients of the Graduate School's 2020 teaching awards.

Sassan Hajirezaie, a fifth-year doctoral candidate in civil and environmental engineering, is a Princeton Energy and Climate Scholars fellow. He received a First Year Fellowship in the Natural Sciences and Engineering. Hajirezaie's recent honors include the Mary and Randall Hack '69 Graduate Award for Water and the Environment from the High Meadows Environmental Institute.

Maria Moreyra Garlock, professor of civil and environmental engineering and co-director of the Program in Architecture and Engineering, who nominated Hajirezaie, described him as "dependable and an invaluable support for me."

Photo by Morgan Kelly

Garlock said Hajirezaie ran two labs, in addition to training four other assistant instructors.

"In my three years at Princeton, I've never come across a teaching assistant as kind and accommodating as Sassan, who changed his schedule around so often for his students in order to make sure we got the help we needed to feel confident and secure about the material," one of Hajirezaie's students explained.

Another student noted that Hajirezaie is an "excellent teacher who ably instructs and inspires a deeper love of the course material in his students," and is an inspiration to continuing study in the department.

Alex Novoselov is a 2020 Ph.D. graduate in mechanical and aerospace engineering (MAE). He has served as a McGraw Center Graduate Teaching Fellow and as secretary of the Graduate Student Government.

In 2019, he won first place for his presentation on cool flames during the MAE Research Day. Novoselov's project, "Turbulent Nonpremixed Cool Flames: Experiments, Simulations, and Models," represented the year's best work from the "Propulsion and Energy Science" discipline. In 2018, he took home the department's Crocco Award for Teaching Excellence.

According to his adviser, Michael Mueller, associate professor of mechanical and aerospace engineering, Novoselov "performed well above expectations" in all of his responsibilities as an assistant instructor.

"Alex's demeanor is such that he tears down all barriers to learning, encouraging students to ask questions and explore the course topics for themselves," Mueller said. "This is an invaluable intrinsic skill that combines careful explanation of complex ideas, endless patience, masterful communication, generosity of his time, and dedicated preparation."

"On top of being accessible, well prepared, and helpful, Alex was happy to help. He never made us feel like we were burdening him with our questions and misunderstandings. He was passionate about the material and excited to teach it to us," a student said.

–By Jessica Fasano

Photo by Noel Valero

ALUMNI LEAD PANDEMIC RESPONSES

Lisa Jackson *86, vice president of environment, policy, and social Initiatives at Apple Inc., was appointed to advise New Jersey on the COVID-19 crisis as part of the Governor's Restart and Recovery Commission. Jackson previously was director of the U.S. EPA. Jackson holds a master's degree from Princeton and a bachelor's degree from Tulane, both in chemical engineering.

Cato Laurencin '80, University Professor and Albert and Wilda Van Dusen Distinguished Professor of Orthopaedic Surgery at the University of Connecticut, published one of the first studies on COVID-19 and racial disparities and chaired a National Academies roundtable on the subject. He also was honored for his outstanding service by the National Academy of Medicine with its Walsh McDermott Medal. Laurencin holds a B.S.E. in chemical engineering from Princeton, a Ph.D. from the Massachusetts Institute of Technology in biochemical engineering/biotechnology, and an M.D. from Harvard Medical School.

Eric Schmidt '76, former CEO of Google and chair of Alphabet, was appointed by New York Gov. Andrew Cuomo to lead a 15-member Blue Ribbon Commission to reimagine the state's use of technology during and after the coronavirus pandemic. Schmidt received his B.S.E. in electrical engineering from Princeton and his Ph.D. from the University of California-Berkeley.

Lisa Jackson

Photos courtesy of the subjects

ALUMNI HONORED FOR RESEARCH AND TEACHING

Frances Arnold '79, a Nobel Prize winner in chemistry, was appointed by Pope Francis to the Pontifical Academy of Sciences. Arnold, the Linus Pauling Professor of Chemical Engineering, Bioengineering, and Biochemistry and director of the Donna and Benjamin M. Rosen Bioengineering Center at Caltech, was also elected to the Royal Society of Great Britain for pioneering advancements in directed evolution. She holds a B.S.E. in mechanical and aerospace engineering from Princeton and a Ph.D. in chemical engineering from the University of California-Berkeley.

Wesley L. Harris *68, who received a Ph.D. in mechanical and aerospace engineering from Princeton and a B.S. in aerospace engineering from the University of Virginia, was elected a fellow of the American Association for the Advancement of Science. He is the C.S. Draper Professor of Aeronautics and Astronautics at the Massachusetts Institute of Technology.

John Ochsendorf *98 was a recipient of an Academy of Arts and Letters Architecture Prize. He recently completed a three-year term as director of the American Academy in Rome and returned to his position of Class of 1942 Professor in architecture and civil and environmental engineering at the Massachusetts Institute of Technology. He holds a B.S.E. from Cornell, an M.S.E. in civil engineering from Princeton, and a Ph.D. from Cambridge.

D. Andrew Vernooy '70, professor of architecture design, structural systems, and urban design at Montana State University, was elected to the College of Fellows of the American Institute of Architects. Vernooy holds a B.S.E. in civil and geological engineering from Princeton, master's degrees in both architecture and engineering from the University of Texas-Austin, and a master's in urban design from Harvard. He was a founding partner of Black + Vernooy Architecture and Urban Design based in Austin.

Mihalis Yannakakis *79, the Percy K. and Vida L.W. Hudson Professor of Computer Science at Columbia, was elected a member of the American Academy of Arts and Sciences. His research interests include the design and analysis of algorithms; complexity theory; combinatorial optimization; game theory; databases; and modelling, verification, and testing of reactive systems. Yannakakis received a Ph.D. in electrical engineering from Princeton.

Frances Arnold

Wesley L. Harris

Mihalis Yannakakis

ALUMNI NAMED TO LEADERSHIP ROLES


Sally Blount


Lance Collins

Photos courtesy of the subjects

Udit Batra *96, who has a Ph.D. in chemical engineering from Princeton and a B.S.E. from the University of Delaware, has been named president and CEO of Waters Corp., a company that manufactures mass spectrometry instruments used in drug discovery and development.

Sally Blount '83 is the first lay person to be appointed CEO of Catholic Charities of the Archdiocese of Chicago. Previously, Blount was the Michael L. Nemmers Professor of Strategy at the Kellogg School of Management at Northwestern University and the school's former dean. Blount holds a B.S.E. in civil engineering from Princeton and a Ph.D. in organizational behavior from Northwestern University.

Gregory Caltabiano '82 is the new president and CEO of FutureDial, a provider of robotics and artificial intelligence for mobile device processing. Earlier leadership roles include president and CEO of Teknovus, president and CEO of ACCO, and president and COO of SOMA Networks. Caltabiano has a B.S.E. in electrical engineering and computer science from Princeton and an M.B.A. from Stanford University.

Lance Collins '81 has been named vice president and executive director of Virginia Tech's new Innovation Campus. Under construction in Alexandria with plans to open in 2024, the school will link graduate education with high-tech industry. Collins moves to Virginia Tech from Cornell University, where he was dean of engineering and was instrumental in the launch of Cornell Tech in New York City. Collins received a B.S.E. from Princeton and a Ph.D. from the University of Pennsylvania, both in chemical engineering.


Tyler Evans

Tyler Evans *92 was named senior vice president of Aerojet Rocketdyne's defense business unit. He joined the company in 2014 as vice president of its Rocket Shop defense advanced programs unit. In his new position, Evans will oversee missile defense, air defense, and tactical and strategic systems. Evans has a B.S. in aeronautical engineering from Virginia Tech, an M.S.E. in mechanical and aerospace engineering from Princeton, and an M.B.A. from Purdue University.


Elizabeth Hunt

Elisabeth Hon Hunt '03 was promoted to shareholder at Wolf, Greenfeld & Sacks, P.C., an intellectual property law firm with offices in New York and Boston. She represents clients primarily in post-grant contested matters before the Patent and Trial Appeal Board. Hunt's B.S.E in electrical engineering is from Princeton and her Ph.D. in electrical engineering and computer science is from the Massachusetts Institute of Technology.


James Iannone

James Iannone '94, who received a B.S.E. in civil engineering from Princeton and an M.B.A. from the Stanford Graduate School of Business, is now president and CEO of eBay Inc. Previously he was COO of Walmart eCommerce, vice president of membership and technology of SamsClub.com, and a vice president of eBay.


Matthew Karmel

Matthew Karmel *82, who received a Ph.D. in mechanical and aerospace engineering from Princeton and an M.B.A. from the INSEAD business school in France, was named CEO at Crenlo Engineered Cabs. The company manufactures engineered operator cabs and roll-over protective structures for heavy equipment and off-highway vehicles. Prior to this appointment, Karmel served as an operating partner at Atlas Holdings.

Rajesh Krishnan '94 was appointed a senior vice president at Oncternal Therapeutics Inc., a clinical-stage biotechnology company focused on developing cancer treatment candidates. Krishnan, who moves from a vice president position Dynavax Technologies Corporation, will oversee chemistry, manufacturing and controls, and manufacturing. He holds a B.S.E. in chemical engineering from Princeton, and an M.S. in chemical engineering and a Ph.D. in biochemical engineering, both from the University of California-Davis.

John Tseng-Chung Lee '85 was promoted from president and COO to CEO at MKS Instruments, a global provider of instruments, systems, subsystems, and process control solutions to improve process performance and productivity. Lee received a B.S.E. from Princeton and an M.S. and Ph.D. from the Massachusetts Institute of Technology, all in chemical engineering.

Celina Jadwiga Mikolajczak *94 was appointed vice president of battery technology at Panasonic, where she and her team will continue to improve lithium-ion cell manufacturing. Previously, Mikolajczak was a technical consultant and director of engineering for Uber and served as a senior manager for cell quality and material engineering for Tesla. She received an M.A. in mechanical and aerospace engineering from Princeton.


Melissa Maquilan Radic

Melissa Maquilan Radic '04 joined IMPACT Community Capital, a registered investment advisor company, as director of investor relations and capital markets. Her experience includes positions at BlackRock in the company's retirement insurance group and then as head of insurance business for the West Coast. Radic earned a B.S.E. in operations research and financial engineering at Princeton and an M.B.A. at the Wharton School of the University of Pennsylvania.

Adwait Ratnaparkhi '92 was appointed executive director of the new master's degree program in Natural Language Processing at the Baskin School of Engineering at the University of California-Santa Cruz. Formerly, he was an executive director at Roku, a TV streaming platform, where he developed natural language understanding and conversational AI technologies. Ratnaparkhi's B.S.E. in computer science is from Princeton and his Ph.D. is from the University of Pennsylvania.

Ruben Rodriguez '85, who earned a B.S.E. in mechanical and aerospace engineering from Princeton, an M.Eng. from the University of California-Berkeley, and an M.B.A. from Stanford University, has been appointed president of the North American branch of MSC Cruises. He will oversee the company's development of a new terminal in Florida and the Ocean Cay MSC Marine Reserve in the Bahamas. Previously, he was CEO of Great Wolf Resorts and executive vice president of ship operations and marketing and guest experience for Carnival Cruises.

Joseph Roxe '95 has been named chief marketing officer at BitSight, a company that rates an organization's cybersecurity performance. Before joining BitSight, Roxe was a marketing executive at Stealth Mode and Consulting, athenahealth, and Rapid 7. He holds an M.B.A. from the Tuck School of Business at Dartmouth College and a B.S.E. in computer science from Princeton.

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