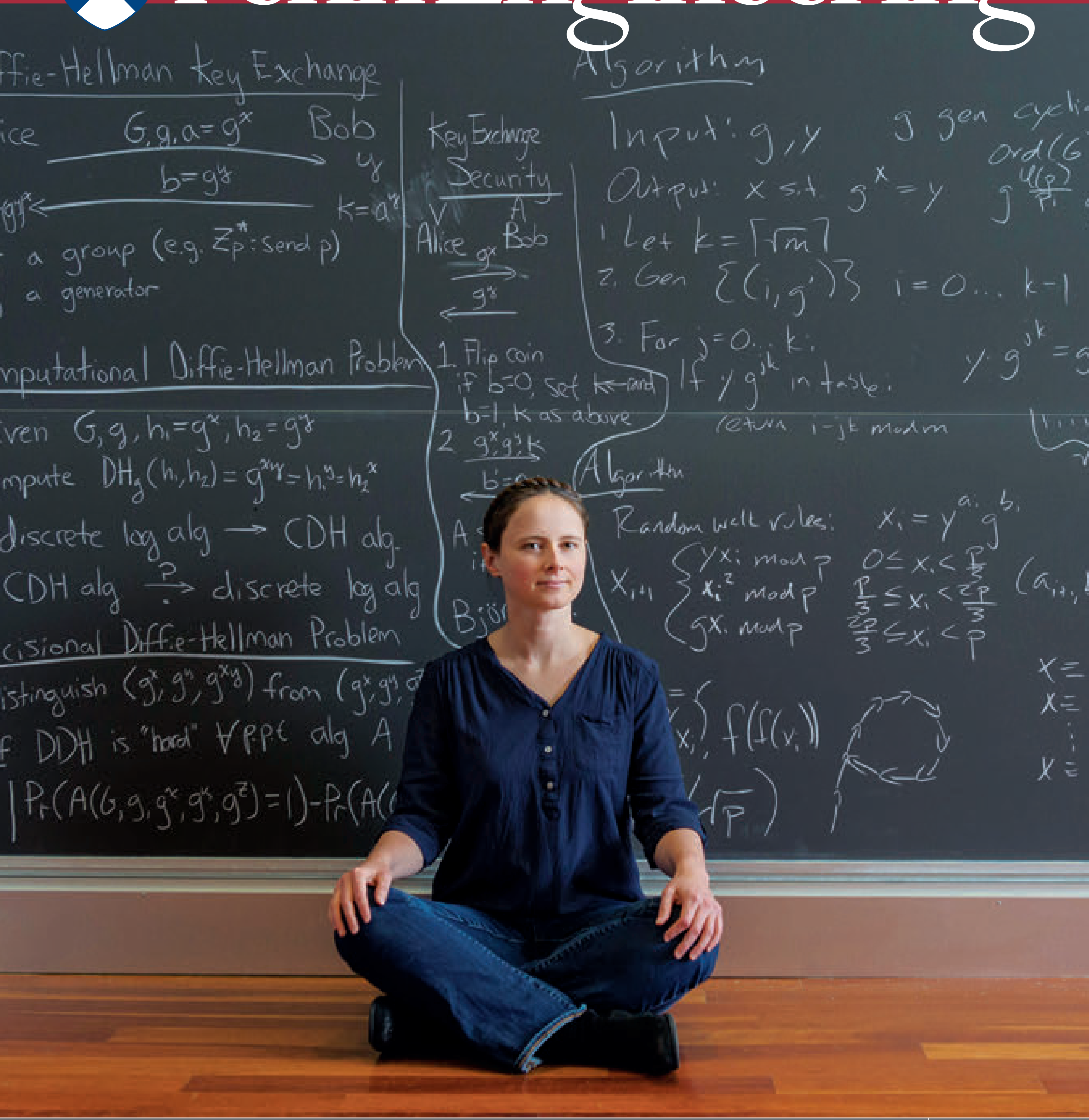
Penn Engineering



UNIVERSITY OF PENNSYLVANIA | SPRING 2016

Hurrah, Pennsylvania!

The Penn Quaker is a universally recognized figure on campus, however the identities of the five students who bring him to life are never revealed. Curiously, when we invited the Quaker to visit the Engineering campus, he seemed to need very little in the way of guidance to find his way around certain laboratories and classrooms, and the Cyber Café even seems to keep a special snack item on hand just for his enjoyment. This year, perhaps the Quaker is portrayed by at least one Penn Engineer?

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University of Pennsylvania
School of Engineering and Applied Science

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Empowering Innovation

How do we create a culture that encourages and fosters technological innovation? I maintain that there are three essential desiderata.

First, we need innovators. Each year at Penn, we welcome an extraordinary group of students who represent the best talent that the world has to offer. Our students are both the recipients and the drivers of Penn Engineering's incubator for the imagination.

Second, we have to create the infrastructure that allows innovators to imagine, design, create and test ideas, and to iterate rapidly and repeatedly until new ideas either fail or are improved and honed to perfection.

Last, we have to surround ourselves with collaborators across disciplines and with partners that connect to the commercial world.

These elements were behind the creation of PERCH, the Penn Engineering Research and Collaboration Hub. This new 11,000 square-foot research facility is located in the heart of Penn's 23-acre Pennovation Works campus, anchored along the southern bank of the Schuylkill River.

PERCH will attract the talent to not only pursue fundamental research on robotics, embedded systems, the "Internet of Things" and other emerging domains of interdisciplinary science and engineering, but also to channel innovative thinking and energies toward technologies and products. These laboratories will enable the cross-fertilization of basic, curiosity-driven research with applied research and development. PERCH is based near startup companies and commercial tech centers that help nucleate new ventures.

Efforts like this are critical to improving the lab-to-market pipeline and supporting the growth of an ecosystem for technology innovation in Philadelphia. Developing this environment for innovation is crucial to our mission. We continually strive to innovate, to accelerate the translation of fundamental engineering discoveries into useful technologies with broad applications, and to create products with both technological and socioeconomic impact.

Small Scale, Big Impact

Imagine a swarm of insect-inspired robots flying through the sky, using tiny sensors that can continuously monitor pollution levels or the use of chemical weapons. This futuristic vision may actually become reality, thanks to the innovative research spearheaded by Igor Bargatin, Class of 1965 Term Assistant Professor in Mechanical Engineering and Applied Mechanics (MEAM). By developing the thinnest freestanding ceramic plates that can be picked up by hand, he has come one step closer to enabling wings that are both lightweight and robust. These wings could be used in flying robots for a variety of environmental and military applications.

"Despite being made up of a brittle ceramic material, the plates are remarkably tough and can recover their original shape after sharp bending," explains Bargatin. "When used to make wings for flying robots, the lightweight plates could potentially enable long flight times without the need for an onboard power source. This stands in stark contrast to existing types of insect-inspired robots, which are not practical for long-term use because they consume so much power."

To construct the freestanding plates, Bargatin and his team combined a process called "atomic layer deposition" with advanced microfabrication techniques. The two-centimeter-wide plates are formed by depositing ultrathin alumina films on a honeycomb-patterned silicon wafer, and then removing the silicon to leave behind only the ceramic material (see back cover). "The secret to our success is the honeycomb pattern, which allows the plates to stay rigid enough to maintain their shape under gravity," says Bargatin.

Currently, the thinnest manmade wing material commonly available is Mylar film. Similar to cling wrap, this material wrinkles easily, sags under its own weight, and generally cannot maintain its shape unless it is stretched on a heavy frame. But the freestanding plates hold promise for overcoming these limitations, potentially enabling the widespread implementation of lightweight insect-inspired flying robots for various sensor applications. Moreover, these plates could lead to the development of novel ultra-strong materials that benefit from nanoscale strength enhancement, which could be used in jet engines or thermionic energy converters.

IGOR BARGATIN
Class of 1965 Term Assistant Professor
Mechanical Engineering and Applied Mechanics

"Igor's work complements existing research at Penn because he combines nanoscale concepts with larger-scale issues, like structural stability and energy conversion," notes Robert Carpick, John Henry Towne Professor and chair of MEAM. "The exceptional facilities here in the Singh Center for Nanotechnology provide him with the tools he needs for this extremely fine-scale fabrication and characterization. It is a unique strength of Penn that makes his innovative work possible."

HARNESSING WASTE HEAT

Bargatin did not always envision becoming a mechanical engineer. As a teenager, he won first place in the All-Russia Physics Olympiad before pursuing a bachelor's degree in theoretical physics at Moscow State University. "My undergraduate research focused on quantum-optics systems, which have inspired a lot of Nobel Prizes, but have a long way to go before they make a big impact on our daily lives," he says. "That's when I started to sense that I wanted to do something more practical."

BARGATIN HAS DEVELOPED THE THINNEST FREESTANDING CERAMIC PLATES THAT CAN BE PICKED UP BY HAND.

During his doctoral studies at Caltech, Bargatin embarked on the challenging transition from theoretical to experimental physics when he decided to work on nanomechanical devices for sensors. His career path took another turn as a postdoctoral scholar in the Department of Electrical Engineering at Stanford, where he started trying to revive the field's interest in research on thermionic energy converters.

In its heyday, this technology was used to directly convert heat to electricity for powering space missions. Here's how it works: electrons evaporate from a hot electrode (i.e., the cathode) into a vacuum gap and are collected by a cooler electrode (i.e., the anode) to create an electric current. "Most of U.S. thermionics research was tied to the space-nuclear program, which ended in 1973," notes Bargatin. "Thermionics research never fully recovered from this blow."

After joining the Penn faculty three years ago, Bargatin and his collaborators received a large grant from the U.S. Department of Energy to breathe new life into this research area by developing highly efficient thermionic energy converters. Recent advances in materials science and microfabrication techniques have translated into radically higher performance and lower manufacturing costs, making thermionic energy conversion an attractive option for both residential and industrial applications.

For example, the devices could be used to generate electricity in homes by harnessing waste heat produced by household water heaters or industrial processes. While the conventional method of producing usable heat and power separately has a typical combined efficiency of 45 percent, combined-heat-and-power systems can operate at levels as high as 80 percent. Moreover, thermionic energy converters could be combined with solar panels to make houses more independent from the power grid.

To roughly double the efficiency of these systems, Bargatin and his collaborators have proposed two key innovations: fabricating higher-quality anode materials, and reducing the size of the gap separating the electrodes to optimize the flow of current. Whether the new devices are used in houses or power plants, they hold promise for reducing greenhouse gas emissions and lowering consumer energy costs.

ENERGIZING ENGINEERS

To inspire the best work from his graduate students, Bargatin fosters a positive, collaborative environment. He encourages students to work independently while remaining accessible and open to new ideas. "Dr. Bargatin has a way of challenging you to learn more, dig a little deeper and try to find the answer yourself," remarks John Cortes, a MEAM doctoral student in the Bargatin lab. "He is always available to answer questions if you get stuck, but at the end of the day, I feel like I

Bargatin demonstrates a Stirling engine with Chen Lin (right) and John Cortes (center), third- and second-year doctoral students, respectively. A Stirling engine can convert the energy from hot water (seen in the cup below the engine) into mechanical work, driving the crankshaft of the engine.

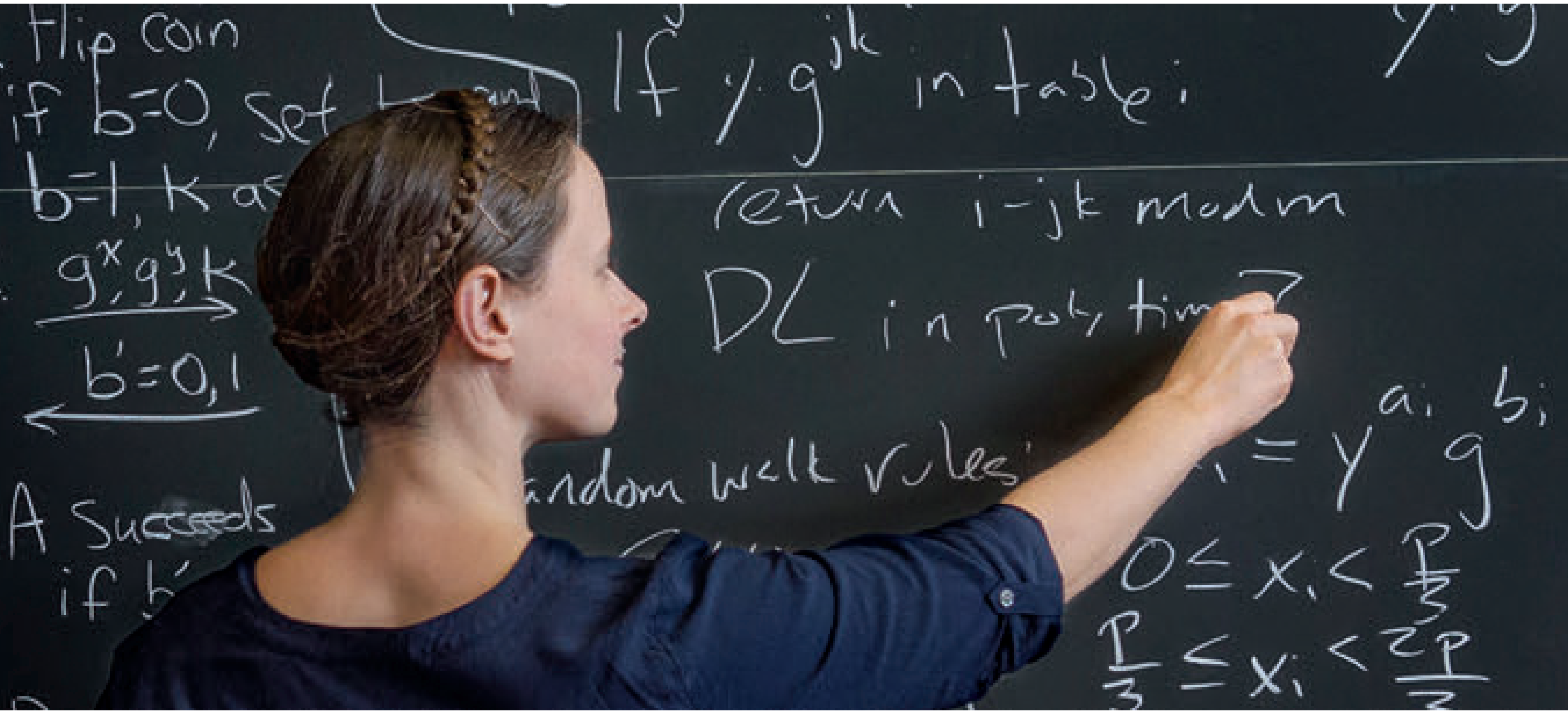
have accomplished a lot with his guidance, which is ideal in engineering."

While teaching lessons for his newly developed course, MEAM 503: Direct Energy Conversion: From Macro to Nano, Bargatin relies extensively on analogies to make the material accessible to students who are completely new to the topic. This tactic has paid off, making the popular course among the most highly rated in the department. Similarly, as the instructor for MEAM 203: Introduction to Thermodynamics, Bargatin has worked hard to explain the abstract and challenging material to a large number of students who enter with varying levels of preparation.

"To help the students learn, Igor overhauled the course, creating a full set of new problems with real-world examples and consequences, and developed new in-class demonstrations to help illustrate the concepts at play," remarks Carpick. "This is leading to positive learning outcomes for the students, thanks to his substantial efforts."

Whether it's in the classroom or the lab, Bargatin is optimistic that his innovative and imaginative approach to engineering will pay off. "I hope that my lessons will get students as excited about research as I am," he says. "Maybe one day they too will be inspired to dream of something new, and figure out whether it has legs to stand on, or wings to fly, for that matter. And hopefully that invention can change the world, at least a little bit."

By Janelle Weaver



Feats to Fortify Internet Security

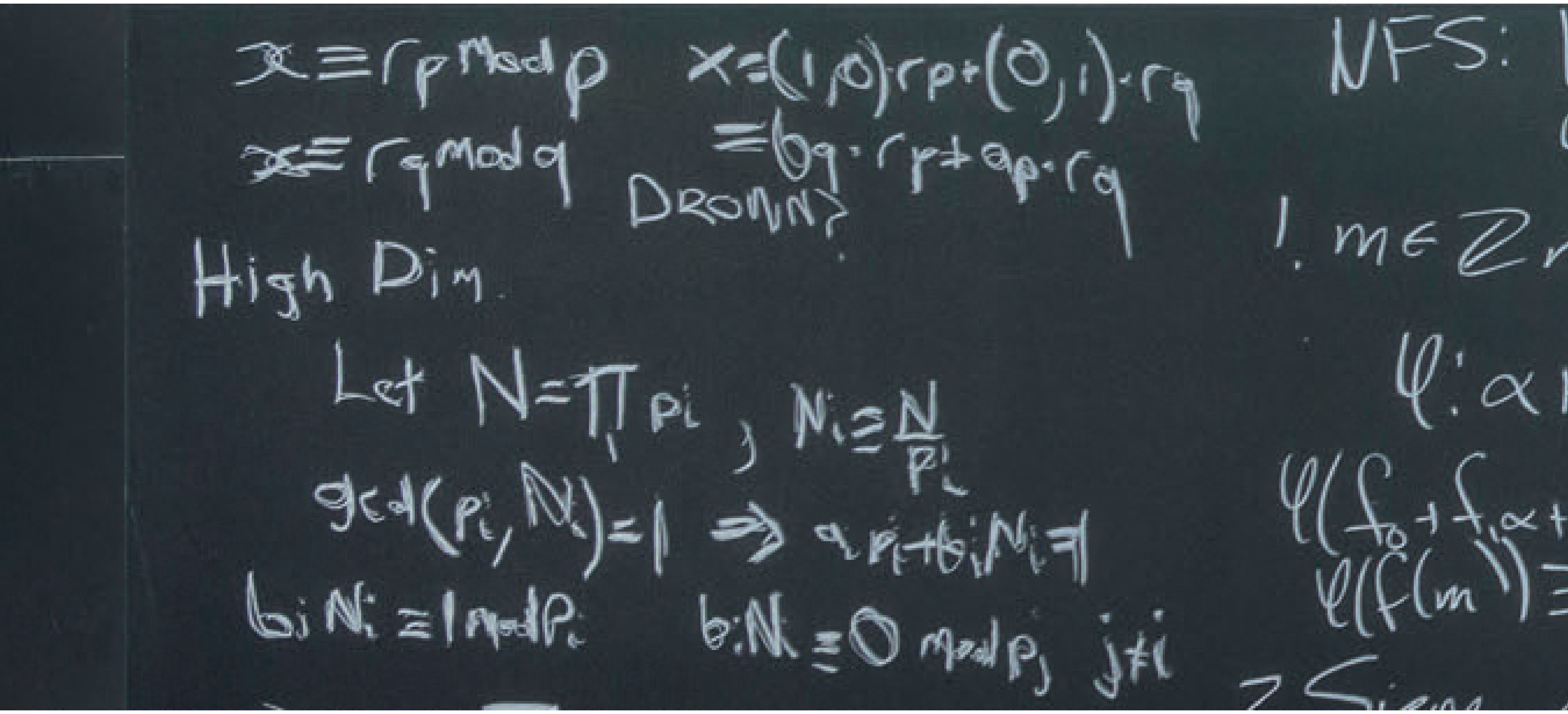
Virtual barricades that keep the world safe from cyber thieves, terrorists, malicious hackers and nefarious actors are reinforced with extremely complex mathematical and computing algorithms. As an influential scholar in the crucial practice and theory of computer security, Nadia Heninger finds consequential digital vulnerabilities, and devises and shares solutions before harm ensues.

"I've made my career in finding subtle cryptographic flaws that turn out to compromise a large number of systems," says Heninger, Magerman Term Assistant Professor in the Department of Computer and Information Science (CIS). She works to make systems more secure by understanding how they fail, generating insights that have prevented grievous losses of data, privacy and security.

HOUSE OF CARDS

"Nadia has helped to discover some of the most interesting and impactful threats to security that affect businesses and individual privacy worldwide," notes J. Alex Halderman, director of the Center for Computer Security and Society at the University of Michigan, and a frequent research collaborator. "She is one of the best people currently bridging the areas of theory and systems in the field of computer security, and she has achieved seemingly magical results in breaking cryptography, combining an excellent level of mathematical depth with a passion for real-world problems that affect the security of millions of people."

Ethical dedication to the public good informs the deft timing with which she works to share her crypto-sleuthing discoveries. "The security of real-world systems can seem like a fortress with a security system described as 'military grade cryptography certified by agencies following best practices,'" says Heninger. "If you think from the perspective of an attacker, it's a house of cards."



Nadia Heninger, Magerman Term Assistant Professor in Computer and Information Science, considers some of the mathematical ideas underlying the security of public-key encryption, which is used to securely transmit information across the internet.

Heninger not only trains her graduate students to spot security vulnerabilities, but also to effectively disclose them so that affected companies and governments can make needed repairs before discoveries are published and flaws are used maliciously. “With all of my recent work, companies have been very responsive and have put out patches and the like,” she says.

HENINGER FINDS CONSEQUENTIAL DIGITAL VULNERABILITIES, AND DEVISES AND SHARES SOLUTIONS BEFORE HARM ENSUES.

OBSOLETE ENCRYPTION

In March 2016, Heninger and collaborators disclosed a serious vulnerability in 33 percent of websites that use HTTPS, the cryptography that secures the web. While there was no evidence the flaw had been exploited, it would have allowed attackers to break encryption and steal or read sensitive communications, including passwords, credit card numbers, trade secrets or financial data. This vulnerability was an example of the potential for catastrophic security failures caused by government policies from the ‘90s that weakened cryptography, according to drownattack.com, created by Heninger and her coauthors. They did not release the attack code (executable in under a minute with a personal computer), and instead shared detailed instructions to protect against this vulnerability.

Another recent example of her clout: Heninger’s 2015 paper, *Imperfect Forward Secrecy: How Diffie-Hellman Fails in Practice,* noted a critical security flaw in eight percent of the top one million websites. On servers supporting obsolete government encryption parameters—designed to allow backdoor surveillance—communications

can be accessed by an attacker using today's more powerful computers. Before that paper appeared in the *Proceedings of the ACM Conference on Computer and Communications Security,* she and her coauthors disclosed the vulnerability to all major web browser companies, which rapidly deployed suggested repairs.

An urgent round of sleuthing began in mid-December 2015 when Juniper Networks cryptically announced that its network devices, used for firewalls and virtual private networks by a high proportion of global businesses, had been compromised with unauthorized, secretly embedded code. Heninger's lab joined ten other researchers in a collaborative race to analyze the implications. "If a significant portion of Juniper systems are vulnerable, that means much of the world's internet network traffic is also vulnerable," says Shaanan Cohney, a second-year doctoral student in Heninger's lab. He noted (in February), "We're still trying to understand how this vulnerability works, when it happened, who is responsible and what else is vulnerable."

HENINGER AND COLLABORATORS DISCLOSED A SERIOUS VULNERABILITY IN 33 PERCENT OF WEBSITES THAT USE HTTPS.

In January, a U.S. congressional committee began investigating claims that subtle flaws in Juniper's technology had been introduced via National Security Agency specifications that created a digital backdoor (for government access). "While our current work focuses on technical topics, not politics, we strongly posit that the use of digital backdoors is dangerous because the U.S. government can't control who will use these," Cohney says.

Heninger and second-year doctoral students Shaanan Cohney (left) and Luke Valenta (center) discuss a new result on mathematical lattices in cryptography.

"We're having a national and international discussion on what the limits of government surveillance should be," adds Heninger. "There's an ethical level to that discussion, a philosophical, political and technical level. My work addresses the technical level. The 'security and privacy trade-off' is language used by politicians and law enforcement—that you can either have privacy or be secure. But that's not how the internet functions. Being able to use cryptography to keep data away from hackers is critical to our security."

CODE-BREAKING HOMEWORK

Heninger joined Penn's faculty in 2013, and appreciates the presence of colleagues in related security, theory, data science and public policy fields. She especially enjoys teaching. "It's fun. You're constantly reevaluating what you're doing and teaching."

Students who take her undergraduate class, CIS 331: Introduction to Networks and Security, often enroll next in CIS 556: Cryptography, a graduate-level course for which she devised a clever way to assess readiness: students must design programs to attack and decrypt each of their six homework problem sets. "Successful students really like this challenge," says Luke Valenta, a second-year doctoral student and teaching assistant. "Hours and sometimes days of struggle with a problem ingrain the concepts in your mind so you actually remember them later on."

Cohney adds, "What makes Dr. Heninger special is her concern for the development of her doctoral students, not just as excellent researchers, but as moral individuals who can analyze their work through the lens of public good and policy."

By Jessica Stein Diamond

Seeking Problem Solvers

Shaping the Next Generation of Doctoral Students

There is a transformation taking place in robotics. As machines become more interactive and integrated into our lives, people from diverse backgrounds are flocking to the field to tackle new challenges. Bhoram Lee and Sonia Roberts, two doctoral candidates in Electrical and Systems Engineering (ESE), are both conducting research that will shape the next generation of autonomous machines, whether it be self-driving cars, delivery drones or Martian rovers. But their interests, backgrounds and skillsets could not be more different.

Lee, a former researcher at Samsung, is fascinated by how robots perceive the world. Roberts, a cognitive scientist-turned-engineer, is interested in how machines move about in it. At Penn, each of these women has found a niche where her abilities can flourish.

EYES LIKE A HUMAN'S

Computers have always been a big part of life for Lee, who grew up in South Korea with an electrical engineer and programmer for a father. After graduating from Seoul National University with bachelor's and master's degrees in mechanical and aerospace engineering, Lee took a job at Samsung, where she spent five years developing algorithms for mobile user interfaces. But an interest in pushing the boundaries of artificial intelligence eventually drew Lee back toward academia. When she learned that Daniel Lee, UPS Foundation Professor in ESE, was producing novel research at the interface of neuroscience and machine learning, she decided to apply to Penn.

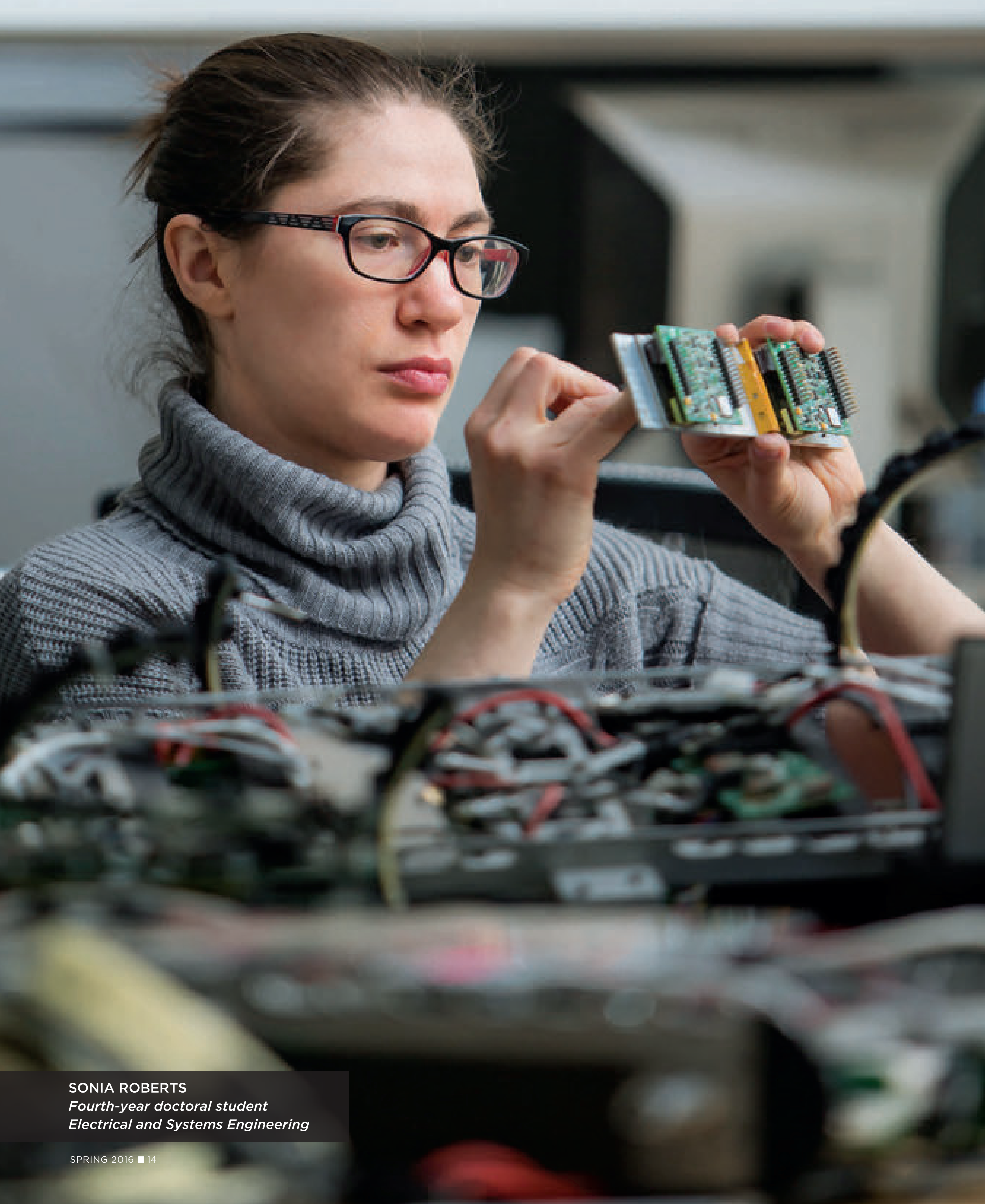
"Bhoram came from an unusual background, being a researcher at Samsung," recalls Daniel Lee, also the director of the General Robotics, Automation, Sensing and Perception (GRASP) Laboratory. "She was on a number of patents, which you don't often see. I could tell she would be a very mature Ph.D. student."

BHORAM LEE'S THESIS RESEARCH USES MACHINE-LEARNING TECHNIQUES TO HELP ROBOTS IDENTIFY OBJECTS IN CHANGING ENVIRONMENTS.

Both Lee and her husband took positions at Penn, and in 2013, they moved to the United States with their two daughters. In her third year now, Lee has finished her coursework and is busy with her thesis research, which involves using machine-learning techniques to help robots identify objects in changing environments. "Robots need to interact a lot with the real world," she remarks. "But if lighting conditions suddenly change, an object can look very different." In order to teach robots to keep their eye on the ball, Lee is writing algorithms that use visual information from the recent past to predict the immediate future.

"Rather than attempting to process every image pixel, Bhoram's algorithms allow a computer to focus on mathematical relationships that prioritize important features of images in video streams," says Stephen McGill, a fellow ESE doctoral

BHORAM LEE
Third-year doctoral student
Electrical and Systems Engineering



SONIA ROBERTS
Fourth-year doctoral student
Electrical and Systems Engineering

student who collaborated with Lee at the Defense Advanced Research Projects Agency (DARPA) Robotics Challenge last year. "Her work is proven on automobiles and humanoid robots."

DESERT WANDERERS

Roberts also took an unusual path into robotics. As a cognitive science major at Vassar College, she became fascinated with the different ways in which intelligence is expressed across the tree of life—and not just in the brain. For instance, as a cockroach scuttles across the ground, its legs react deftly to changing terrain, much faster than would be possible if they were relying on signals from the animal's motor cortex. "I became interested in whole-body approaches to intelligence, and the easiest way to experiment on that is to build an organism," she notes. "That got me into robotics."

ROBERTS BECAME FASCINATED WITH THE DIFFERENT WAYS IN WHICH INTELLIGENCE IS EXPRESSED ACROSS THE TREE OF LIFE.

Her interest in replicating animal behavior in machines is what led Roberts to join the laboratory of Daniel Koditschek, Alfred Fitler Moore Professor in ESE, who also collaborates closely with senior researchers in biology and neuromechanics. "Sonia is a very bold and original thinker," Koditschek says. "She's trying to discern the difficult and elusive problem of teasing apart form and function, and in turn design that intelligence in artificial bodies. And she's doing it with great forethought and planning."

Roberts is now in her fourth year at Penn, has finished her coursework, and is collaborating with researchers at the U.S. Department of Agriculture to design robots that are more adept at walking in sand. In geology, ecology and climate change research, there's a great need for machines that can move about independently in deserts, collecting data without getting stuck.

"Sonia is a great collaborator, and she brings with her a wealth of information from a field that most of us know very little about," says Gavin Kenneally, a fellow doctoral student in Koditschek's lab who collaborates closely with Roberts. "She is always happy to discuss our research and never at a loss for an opinion."

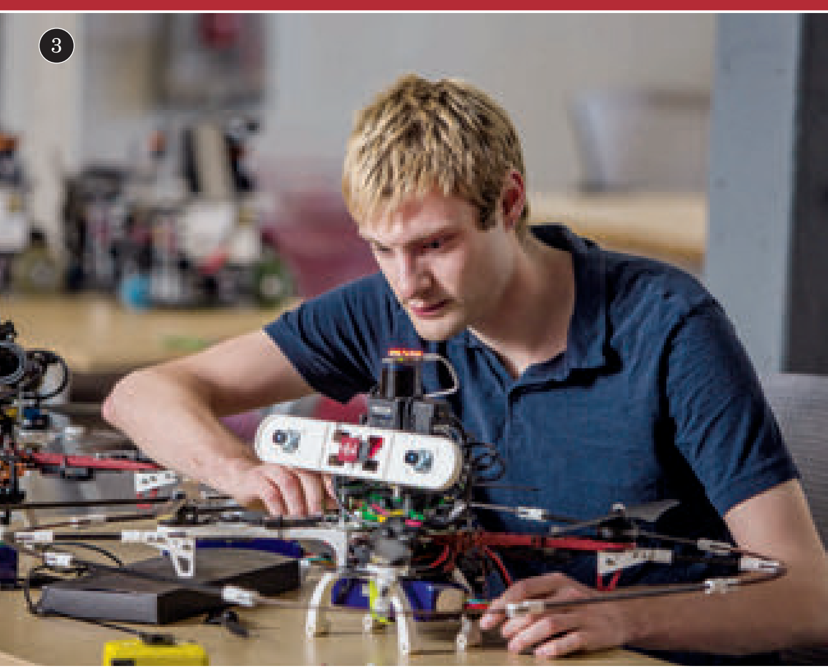
ALL-INCLUSIVE

Electrical engineering is working to overcome one of the widest gender gaps of any STEM field, where women comprise less than 20 percent of all doctoral graduates nationwide. As the community becomes more inclusive and diverse, stereotypes about the "typical" electrical engineer are beginning to fade. "What's happening is the field of robotics is becoming less siloed and more interdisciplinary," notes Daniel Lee. "This is a great time for women in engineering."

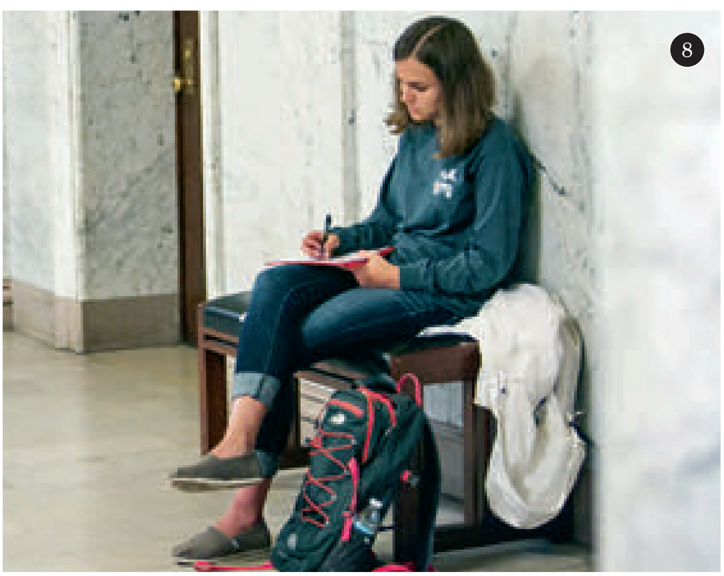
Koditschek agrees. "We need engineers from all backgrounds in order to solve the problems we are looking to solve. We need more people interested in animal physiology, more people interested in cognitive science and in philosophy. When you find the creativity, power, and nettle of a prospective student like Sonia, you immediately want to get her involved."

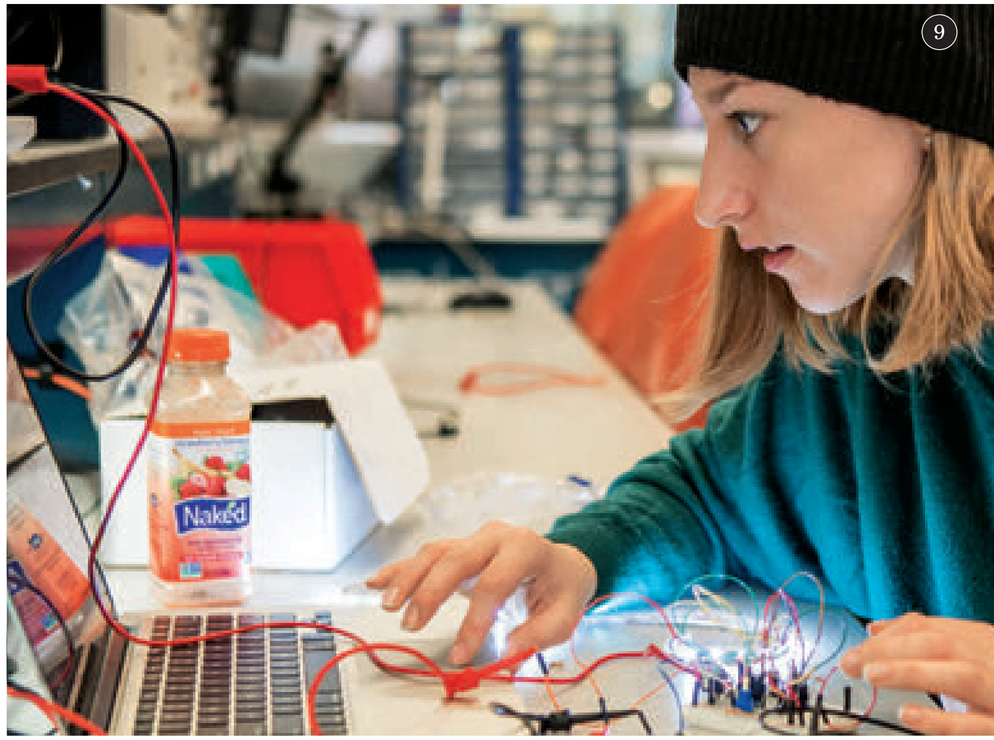
By Madeleine Stone

On Our Camera Roll



1. Students bask in the unexpected warmth of the first day of spring. **2.** A team of programmers enjoys a good inside joke. **3.** Michael Watterson, third-year doctoral student, adjusts the status LED on a quadrotor at PERCH, the Penn Engineering Research and Collaboration Hub. **4.** In the MEAM machine shop, undergraduate Lincoln Talbott prepares to mill a displacer bushing tube used in the construction of a Stirling engine. **5.** Taking a moment to check email messages in the “outdoor office.”





6. PennApps XIII, the world's largest student-run hackathon, featured the happiest of hackers and mascots. **7.** Undergraduates combine their quest for nourishment with a chance to check results at the Cyber Café. **8.** The Towne hallway offers a convenient study spot for students awaiting the start of class. **9.** Bioengineering undergraduate Caroline Lachanski attempts to use music to illuminate an LED light strip and modulate its intensity in ESE 190: Silicon Garage. **10.** Construction on the new façade of PERCH is taking shape.

Scientific Computing at Penn

New Degree Merges the Traditional with the Experimental

As technical, environmental, economic and social challenges become more complex, engineers must prepare to meet the increasing demands of their profession. A graduate education that fuses scientific inquiry with practical application of knowledge isn't enough. Instead, leading professional practice programs, like the degrees offered within the Penn Engineering master's program, combine collaborative engagement with instruction from industry-experienced faculty in order to help professionals advance their problem-solving and leadership capabilities.

"I want to pursue a career in bioinformatics and apply data analysis and predictive modeling in a clinical setting," says Francine (Frankie) Leech. "Learning from accomplished, passionate professors along with professionals from diverse backgrounds is essential to achieving my goals." Leech is one of eight in a cohort enrolled in the School's newest master's degree offering in Scientific Computing. This degree provides a rigorous computational foundation designed to help engineers, scientists, mathematicians or computer scientists learn advanced numerical methods, algorithm development for high-performance computational platforms, and the analysis of large datasets.

LEECH IS ONE OF EIGHT IN A COHORT ENROLLED IN THE SCHOOL'S NEWEST MASTER'S DEGREE OFFERING IN SCIENTIFIC COMPUTING.

"Frankie is a great fit for the Scientific Computing degree, which gives students the flexibility to specialize in different computational science

FRANCINE LEECH
Master's student, Scientific Computing

application areas," remarks Talid Sinno, professor in Chemical and Biomolecular Engineering (CBE) and director of the master's in Scientific Computing. "We're the right choice for those who value being part of a program that is forward-leaning to the point of being somewhat experimental."

Leech is starting her master's coursework while simultaneously finishing her last year in undergraduate biology classes at Bryn Mawr College, making her part of an increasing number of current undergraduate students opting to take advantage of Penn Engineering's submatriculation program option. "I'm a peer mentor at Bryn Mawr and tell everyone about the great opportunity in the submatriculation program at Penn Engineering," she says. She finds that Scientific Computing melds her two biggest interests: math and biology. "I want to apply the quantitative methods from the program to unravel unanswered questions in biological systems," notes Leech.

A UNIQUE APPROACH TO PROBLEM SOLVING

Key to achieving those goals is her involvement with the Penn Institute for Computational Science (PICS), also a part of her graduate degree program. PICS serves as a home for a diverse group of researchers who leverage high-performance computing to study complex systems.

"Scientific Computing master's students participate in PICS via technical, hands-on workshops, weekly symposia featuring speakers from across the nation and an annual conference where they hear from researchers who are leaders in diverse topics related to scientific computing," explains PICS director David J. Srolovitz, the inaugural Joseph Bordogna Professor of Engineering and Applied Science, who holds joint appointments in the Departments of Materials Science and Engineering and in Mechanical Engineering and Applied

Mechanics. "At PICS, people from different disciplines collaborate to develop unique approaches to problem solving, which is an integral part of graduate training."

Leech's master's degree will position her and her cohort members as leading candidates for some of the most in-demand jobs requiring advanced computing, modeling and simulation. Graduates could use their skills in a wide range of careers, such as predicting a new drug's side effects, designing advanced security technology, identifying what controls the manufacturing yields in the microelectronics industry, or testing safety features in new equipment designs. "Our goal is to train scientific analysts who are well versed in science and engineering and who can tackle modern problems that require sophisticated computational tools," says Sinno.

DELIVERING A COMPETITIVE ADVANTAGE

The Scientific Computing degree is one of 15 master's degrees currently offered by Penn Engineering. Each is grounded in up-to-the-minute research findings and the needs of industry and society. "In this way, we stay responsive to the career and personal interests of our students, as well as the needs of today's high-tech world and economy," says Jan Van der Spiegel, associate dean of professional programs and director for undergraduate advising. Students are attracted to Penn Engineering's master's program for its rigor, interdisciplinary approach, project-oriented courses and opportunities for involvement in advanced research. "We resonate with those just starting careers, those who want to advance their careers and those professionals who are interested in crossing careers," notes Van der Spiegel, also professor in the Department of Electrical and Systems Engineering.

Carefully developed curricular offerings have increased interest in Penn Engineering's master's degrees since the program's inception. Hundreds of applications are received annually for limited cohorts in each of the program's degrees. "We try to keep the cohorts small, which has made our program, overall, more and more competitive," he adds.

Francine Leech works with Talid Sinno, professor in Chemical and Biomolecular Engineering and director of the master's in Scientific Computing.

A sense of community is also a distinct difference that appeals to students like Leech. "I especially appreciate the small, personalized experience," she states. "We all have different backgrounds and are at different points in our career development, and sharing resources and encouraging each other is the norm."

PENN ENGINEERING RESONATES WITH THOSE JUST STARTING CAREERS, ADVANCING THEIR CAREERS AND PROFESSIONALS WHO ARE INTERESTED IN CROSSING CAREERS.

In order to attract the most forward-thinking candidates and respond to prospective student interest in an innovative advanced degree program, the master's program offers two additional benefits: the aforementioned submatriculation program, which attracted Leech to Penn Engineering, and a dual-degree program option. "Our dual-degree programs offer admitted students training in both engineering and computer science along with their MBA from The Wharton School or JD from Penn Law," says Van der Spiegel.

The proof of success of any educational program is what happens after its students graduate, and the engineering master's program has plenty of impressive proof points. "Our graduates are highly sought after by employers, government organizations and academia," he continues. "We have an alumni presence now in world-renowned companies like Google, Oracle and Facebook; on Wall Street at institutions like Bloomberg and Morgan Stanley; in medicine, transportation and energy; at Penn or other top universities pursuing doctorates; and as successful entrepreneurs. We're preparing professionals who have the ability to take the lead in developing workable solutions to the complex problems of today and tomorrow."

By Amy Biemiller

Jonathan Brassington

Navigating the Business of Technology

It seems Jonathan Brassington has always been just ahead of schedule.

The co-founder and CEO of the Philadelphia-based digital transformation company LiquidHub arrived in the U.S. from his native Guyana to begin his undergraduate studies at the tender age of 16. By the time he turned 20, he was enrolled in Penn Engineering's master's program in Telecommunications and Operations Strategy. Before he graduated from Penn two years later, he had already entered the workplace at a time in which the internet business landscape was just taking shape. "I graduated (as an undergraduate) with a math and science degree at possibly the most perfect time," admits Brassington with a smile.

AFTER GRADUATING, BRASSINGTON FOCUSED ON BECOMING A TELECOMMUNICATIONS ENGINEER AND DESIGNING THE FUTURE OF THE INTERNET BACKBONE.

Considering his knack for timing, it should come as no surprise that LiquidHub, which Brassington co-founded at age 25, experienced near-immediate meteoric growth upon its inception in 2001. From its humble roots, the company is now a relative behemoth, employing more than 2,000 professionals in 12 offices on 3 continents. It also appears that Brassington will need to add more shelf space for all the awards he and LiquidHub continue to earn, including multiple years of "Best Places to Work" awards from the *Philadelphia Business Journal* and an appearance on the *Forbes* 2014 list of "America's Most Promising Companies."

COLLISION OF CULTURES

The youngest of six brothers before a sister arrived, Brassington was raised in an environment that reflected the collision of cultures in Guyana, the small South American country nestled between Venezuela and Suriname. "Due to a history of British colonization, I grew up in a British environment with a very cosmopolitan, mixed culture," says Brassington. "We were the only English-speaking country in South America, and we were actually more culturally linked with the Caribbean than the rest of Latin America."

When Brassington embarked for Misericordia University, a Catholic liberal arts school in Dallas, PA, he stayed under the care of his aunt, a Sister of Mercy nun. After graduating with a joint degree in Computer Science and Mathematics, Brassington looked to pursue his budding interest in technology. "My vision at the time was focused on becoming a high-end telecommunications

JONATHAN BRASSINGTON
Co-founder and CEO, LiquidHub

engineer and designing the future of the internet backbone," he recalls.

That vision, in addition to the fact that he had decided he wanted to stay in the city after meeting Philadelphia native Linda Zebrowski (now his wife), led him to apply to Penn Engineering's telecommunications master's program in 1995. It also didn't hurt that he could continue to cultivate his now-passionate fandom of Philadelphia teams. "I'm a rabid Eagles fan," admits Brassington, before adding, "Penn Engineering was an early leader in telecommunications engineering and research. It was the logical place to go."

CHANGING TRAJECTORY

At Penn, it didn't take long for Brassington to reap an unexpected benefit: the multidisciplinary nature of the curriculum allowed him access to courses in the Operations and Information Management department at The Wharton School. Suddenly, his focus shifted from pure engineering to the application of similar technology in the business landscape. "The trajectory of what I thought I wanted to do changed," Brassington says. "I started to get much more interested in the way the internet could be applied to business."

Even before his 1997 graduation from Penn, Brassington started work at an internet services consulting firm called Broadreach Consulting. Because the industry was in its infancy, the environment was rife with opportunity for young professionals like Brassington to step into leadership roles and work immediately with established Fortune 500 companies. Wasting little time in capitalizing on that experience, Brassington launched LiquidHub with two fellow Broadreach employees, Rob Kelley and Leighton Yohannan, four years later. The company was named LiquidHub in order to call to mind the adaptability of a liquid and the centralized focus of a hub in joining multifaceted parts. In its first iteration, LiquidHub worked mainly with companies in the financial services and healthcare industries, considering the ways technological innovation could solve its clients' problems. Brassington quickly found himself relying upon the connections he made at Penn Engineering to inform many of his business decisions. "Those were very powerful learning experiences," he says of his time at Penn. "You attend university to get an education, but you leave with much more, including a lifelong network to cultivate."

"THE OPPORTUNITY FOR TECHNOLOGY ACROSS ALL INDUSTRIES IS MASSIVE," SAYS BRASSINGTON. "WE'RE LIMITED ONLY BY OUR IMAGINATION."

Today, Brassington and his team are looking to position themselves ahead of the curve once again with a revitalization of LiquidHub. Brassington describes his present-day company as a "convergence of a traditional technology systems integration firm and a marketing agency," and the company now features a number of market-specific accelerators, including LiquidAnalytics, LiquidConnect, and LiquidVentures. Despite the growing challenges of an increasingly complex marketplace and his business's expansion, Brassington sees reason for optimism. "As business becomes more digital, the opportunity for technology across all industries is massive," he says. "We're limited only by our imagination in terms of our growth potential."

If his history is any indication, Brassington will certainly remain one step ahead of the pack.

By Eric McCollom

Face to Face with the Penn Quaker

This year, it is rumored that the Penn Quaker is animated by five alternating students, four of whom are Penn Engineers! Their identities are a well-kept secret and, consequently *Penn Engineering* magazine was not able to confirm or deny the speculation. However, when invited to the Engineering complex for a photo shoot and interview, the Quaker was revealingly at home in the School's hallways and classrooms.

We've been told you're a man of few words. Thank you for consenting to this interview.
Actually, I'm a man of no words, at least spoken ones. My interviews are either conducted through a "translator" or in writing. No one has ever heard me utter a syllable.

How old are you?
Very. Think Ben Franklin.

It really wouldn't be fair to ask if you have a favorite school at Penn, but do you have a favorite school at Penn?
No, but I have found myself gravitating to Engineering recently. I seem to be thinking more and more like an engineer, and sometimes I imagine myself as a SEAS student, tinkering in the labs and bringing my wildly innovative ideas to the workbench, just like my buddy Ben used to do.


PENN
SPORTS
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What is the origin of your name?
Penn's athletic teams were nicknamed "the Quakers" by sportswriters back in the late 19th Century. Though the University is not formally associated with the Society of Friends, or Quakers, the city of Philadelphia and its founder, William Penn, most certainly were. As the official mascot of our teams, my name was a given.

It has been remarked that you're not an especially intimidating mascot. What's your take on that?
While people have mistakenly referred to me as the "Fighting Quaker," I believe it's possible to kill the competition with kindness. Opposing teams often find my smile inscrutable and worrisome—it keeps them off guard. A certain tiger even finds me menacing.

What's your favorite game-time snack?
Toast.

Do you wear a Fitbit?
No, but I love the technology. I get a great workout and burn plenty of calories leading cheers, running around meeting and greeting fans and taunting the opposition. I am, after all, a member of the cheer team and an NCAA Division I athlete.

We've noticed you always wear the same outfit. What's with that?
The same question was often asked of Steve Jobs. Not having to choose a different outfit all the time eliminates "decision fatigue" and allows me to concentrate on the more important issues of game strategy and keeping the Red and Blue energy high.

And those shoes, where do you find such a size?
Back in the day, I just went to the neighborhood cobbler and had them custom made. These days, I shop for shoes where Shaq shops.

Boys want to be you and girls want to be with you. What's it like, being a Big Man on Campus?
I love attending special events, being given the best seat in the house at games, hanging with the cheerleaders, and generally being treated like a celebrity. President Gutmann is a personal friend, and if I were to drop by Dean Kumar's office, for instance, I'd probably find the door open even without an appointment.

By Patricia Hutchings

HONORS & AWARDS

Robert Carpick, *John Henry Towne Professor and Chair of Mechanical Engineering and Applied Mechanics,* was elected Fellow of the Society of Tribologists and Lubrication Engineers (STLE). STLE is the premier technical society serving the needs of more than 13,000 individuals and 200 companies and organizations that comprise the tribology and lubrication engineering business sector.

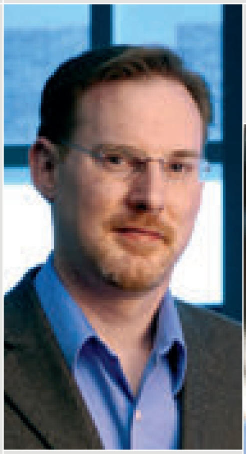
Nader Engheta, *H. Nedwill Ramsey Professor in Electrical and Systems Engineering,* was named a National Academy of Inventors (NAI) Fellow, and will receive an Honorary Doctorate from Aalto University, Finland, in October 2016.

David Issadore, *Assistant Professor in Bioengineering,* was named a recipient of the 2016 Young Scholars Award from the American Cancer Society, and was awarded the IEEE Philadelphia Section Young Engineer of the Year Award.

Ali Jadbabaie, *Alfred Fitler Moore Professor of Network Science in Electrical and Systems Engineering,* was named a 2016 National Security Science and Engineering Faculty Fellow. This program engages the next generation of outstanding scientists and engineers in the most challenging technical issues facing the Department of Defense.

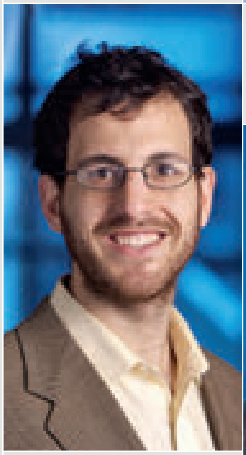
Daniel Koditschek, *Alfred Fitler Moore Professor in Electrical and Systems Engineering,* received the 2016 IEEE RAS Pioneer Award "for his seminal contributions to the mathematical and empirical foundations of robotics, leadership in robotics research, and inspired mentorship of the next generation of roboticists." Koditschek was also named a Department of Defense National Security Science and Engineering Faculty Fellow.

Daniel Lee, *UPS Foundation Professor in Transportation in Electrical and Systems Engineering,* was elected Fellow of the Association for the Advancement of Artificial Intelligence (AAAI). The AAAI is a scientific society devoted to advancing the scientific understanding of the mechanisms underlying thought and intelligent behavior and their embodiment in machines.



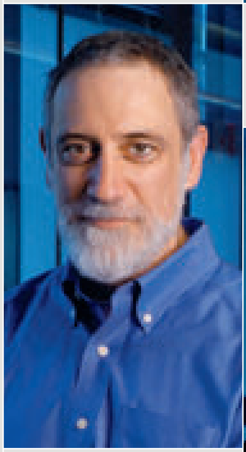
Robert Carpick

Nader Engheta



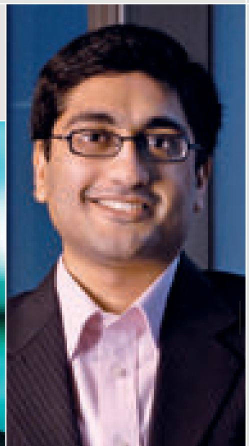
David Issadore

Ali Jadbabaie



Daniel Koditschek

Daniel Lee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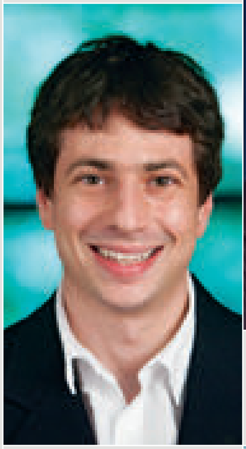
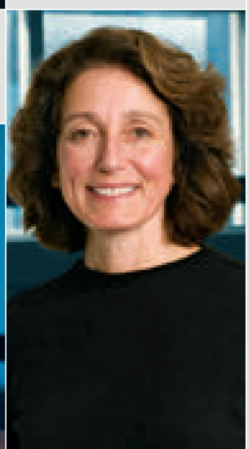

Aaron Roth


Susan Margulies


Karen Winey


Beth Winkelstein


Shu Yang

Rahul Mangharam, *Associate Professor in Electrical and Systems Engineering,* and **Aaron Roth,** *Raj and Neera Singh Assistant Professor in Computer and Information Science,* each received a 2016 Presidential Early Career Award for Scientists and Engineers (PECASE). Awardees are selected for their pursuit of innovative research at the frontiers of science and technology and their commitment to community service as demonstrated through scientific leadership, public education, or community outreach. The Presidential Early Career Awards highlight the key role that the White House Administration places in encouraging and accelerating American innovation to grow the nation's economy and tackle its greatest challenges.

Susan Margulies, *George H. Stephenson Term Professor in Bioengineering,* received the Trustees Council of Penn Women 2016 Provost's Award for her contributions to advancing the role of women in higher education and research at Penn.

Karen Winey, *TowerBrook Foundation Faculty Fellow and Professor in Materials Science and Engineering,* was named an American Chemical Society Division of Polymeric Materials: Science and Engineering (PMSE) Fellow for "outstanding contributions to the understanding of polymer nanocomposites and ion-containing polymers through quantitative scattering and microscopy studies."

Beth Winkelstein, *Vice Provost for Education at Penn and Professor in Bioengineering,* was awarded the 2016 American Society of Mechanical Engineers (ASME) Van C. Mow Medal. This annual honor "is bestowed upon an individual who has demonstrated meritorious contributions to the field of bioengineering through research, education, professional development, leadership in the development of the profession, mentorship to young bioengineers, and with service to the bioengineering community."

Shu Yang, *Professor in Materials Science and Engineering,* was named the recipient of the 2016 George H. Heilmeier Faculty Award for Excellence in Research for "pioneering the synthesis and fabrication of responsive nano- and microstructured soft materials."

John A. Quinn, *Professor Emeritus in Chemical and Biomolecular Engineering,* died on February 8, 2016. He was 83 years old.

Dr. Quinn received a bachelor's degree in Chemical Engineering from the University of Illinois in 1954 and a Ph.D. from Princeton University in 1958. After spending 13 years on the faculty at Illinois, he joined the Penn faculty in 1971 and was named the first recipient of the Robert D. Bent professorship in 1978. He served as Chairman of the Department from 1980 to 1985.

Dr. Quinn's distinguished career spanned over 50 years, during which he taught hundreds of undergraduate and graduate students, supervised over 40 doctoral dissertations, and mentored numerous junior colleagues. His former graduate students, four of whom have been elected to the National Academy of Engineering, populate the most distinguished ranks of their profession.

In the course of his pioneering research on mass transfer and interfacial phenomena, Dr. Quinn and his students devised a number of simple yet elegant experiments to elucidate the role of the interface in transfer between phases. In later years, his work focused on problems relating to bioengineering and biotechnology, to transport through synthetic membranes, and to the application of membranes in chemical processes and in systems of medical and biological relevance. He is author or co-author of more than 100 research papers and review articles. In recognition of his research contributions, Dr. Quinn was elected to the National Academy of Engineering in 1978 and to the American Academy of Arts and Sciences in 1992.

Dr. Quinn is survived by his wife Frances; their children, Sarah Quinn Christensen, Becket Quinn McNab and John Edward Quinn; four grandsons, Bradford, Christopher, Edward and John; two sisters, JoAnn and Virginia; and one brother, James.

To learn more about the life of Dr. Quinn, please visit: seas.upenn.edu/memoriam-quinn

Stuart W. Churchill, *Professor Emeritus in Chemical and Biomolecular Engineering,* died on March 24, 2016. He was 95 years old.

Dr. Churchill received bachelor's degrees in both Chemical Engineering and in Mathematics in 1942 and a Ph.D. in 1952, all from the University of Michigan. After spending 15 years on the faculty at Michigan, he joined the Penn faculty in 1967, accepting the Carl V. S. Patterson professorship. He went on to earn one of Penn's first Medals for Distinguished Service in 1993.

Dr. Churchill was a leader in the fields of combustion, heat transfer, and fluid dynamics for over half a century. He was a gifted teacher and mentor, advising 20 doctoral students during his time at Penn. In recognition of his extraordinary career, Dr. Churchill was elected a member of the National Academy of Engineering (NAE) in 1974, and was later honored with the NAE Founders Award in 2002 for "outstanding leadership in research, education, and professional service, and for continuing contributions in combustion, heat transfer, and fluid dynamics for over a half century."

Dr. Churchill was author of 215 papers, several textbooks and six books before his retirement in 1990, after which he continued writing more than 110 additional papers. He was an active member of the American Institute of Chemical Engineers (AIChE), serving as its president in 1966. In 2008, the AIChE designated him as one of the 100 most distinguished chemical engineers of the modern era. On the occasion of his 90th birthday, Dr. Churchill was honored with a Festschrift in the August 2011 issue of *Industrial and Engineering Chemistry Research,* a leading archival journal in chemical engineering.

Dr. Churchill is survived by his wife Renate and his children, Stuart L., Diana, Catherine and Emily.

To learn more about the life of Dr. Churchill, please visit: seas.upenn.edu/memoriam-churchill

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John F. Lehman

The Value of Service

Over the course of his diverse and successful career, Philadelphia native John Lehman (GR'74) has served as Secretary of the Navy, worked as a private equities investor, authored books, and offered lectures on military and political history as an honorary fellow at his alma mater in Cambridge, England. He holds advanced degrees in international law, diplomacy and American foreign policy, and he has crafted strategic defenses to national security threats.

Throughout his life's work, the value Lehman places on service has remained constant. "It was always part of my upbringing," he recalls. "Whether in charitable works or in education, everyone has an obligation to provide their time, attention, and talents to their community." Below, Lehman shares some of the highlights of his longstanding service to his country and to Penn Engineering.

What about the Navy appealed to you?
For me, joining the military was a way to provide service by doing what I do best, which turned out to be flying jets. The roots of military service also run deep in my family. My fourth great-grandfather was a physician in Washington's army at Valley Forge, and another was a doctor in the Union Navy during the Civil War. My dad and four of my uncles served in the Navy during World War II—a fifth uncle "defected" to the Army.

What inspired you to join the Penn Engineering Board of Overseers?
In addition to my alumni ties to Penn, everything in my professional life, whether it was flying, leading the Navy or buying and selling companies, has involved engineering in one way or another. I've always felt this was the ideal engineering school.

What stands out from your service to Penn?
I've benefitted tremendously throughout my time with the School. Penn Engineering is at the forefront of research and teaching expertise, and it is a real privilege to be on the Board with so many accomplished people. There's a tangible and unique engagement and collaboration among the dean, faculty leaders, and board members.

What do you think of "Penn Engineering 2020?"
It's a very clear, realistic strategic plan of action that will bring the School to a new level of recognition and excellence. Great advances in science and engineering come from collaborations of great minds, so I'm particularly enthusiastic about creating more endowed chairs in order to expand our world-class faculty.

What makes you so passionate about engineering education?
One of my major interests is STEM programs in American education. There is a lack of teachers with degrees in science and engineering, so students tend to be taught in a rote way that kills their interest. Penn's students generate a lot of excitement with their projects and competitions, like the PennApps hackathon. It's important to me that Penn Engineering is at the cutting edge of pedagogical techniques so that we can transmit that excitement for scientific discovery to younger students.

You have had a long career, but do you ever feel that you may be leaving something undone?
Even though I have five earned degrees, none are in engineering. In my next life, I'm going to get a degree from Penn Engineering!

Penn Engineering Board of Overseers

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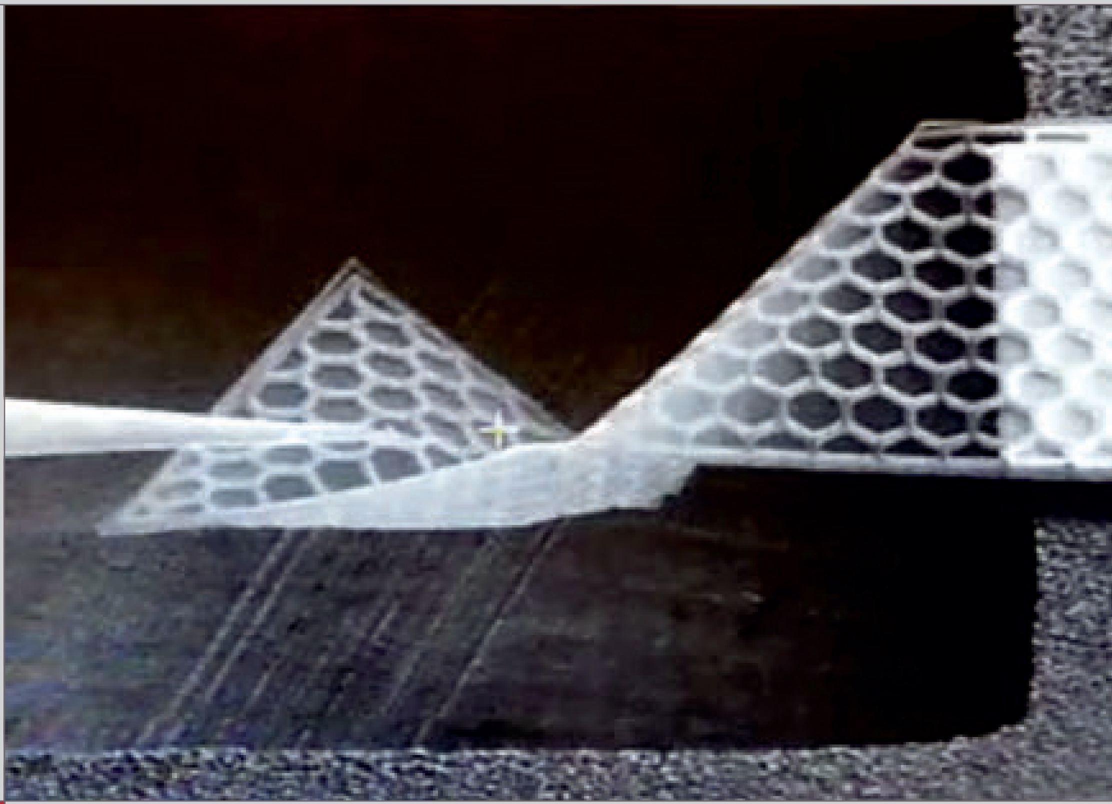
A plate of aluminum oxide is seen undergoing extreme deformation without fracture. Although aluminum oxide is a brittle ceramic in everyday life, the plate is extremely robust due to its nanoscale thickness (<50 nm). This is just one manifestation of what the creator of these plates, Igor Bargatin, Class of 1965 Term Assistant Professor in Mechanical Engineering and Applied Mechanics, deems "nanoscale magic."



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