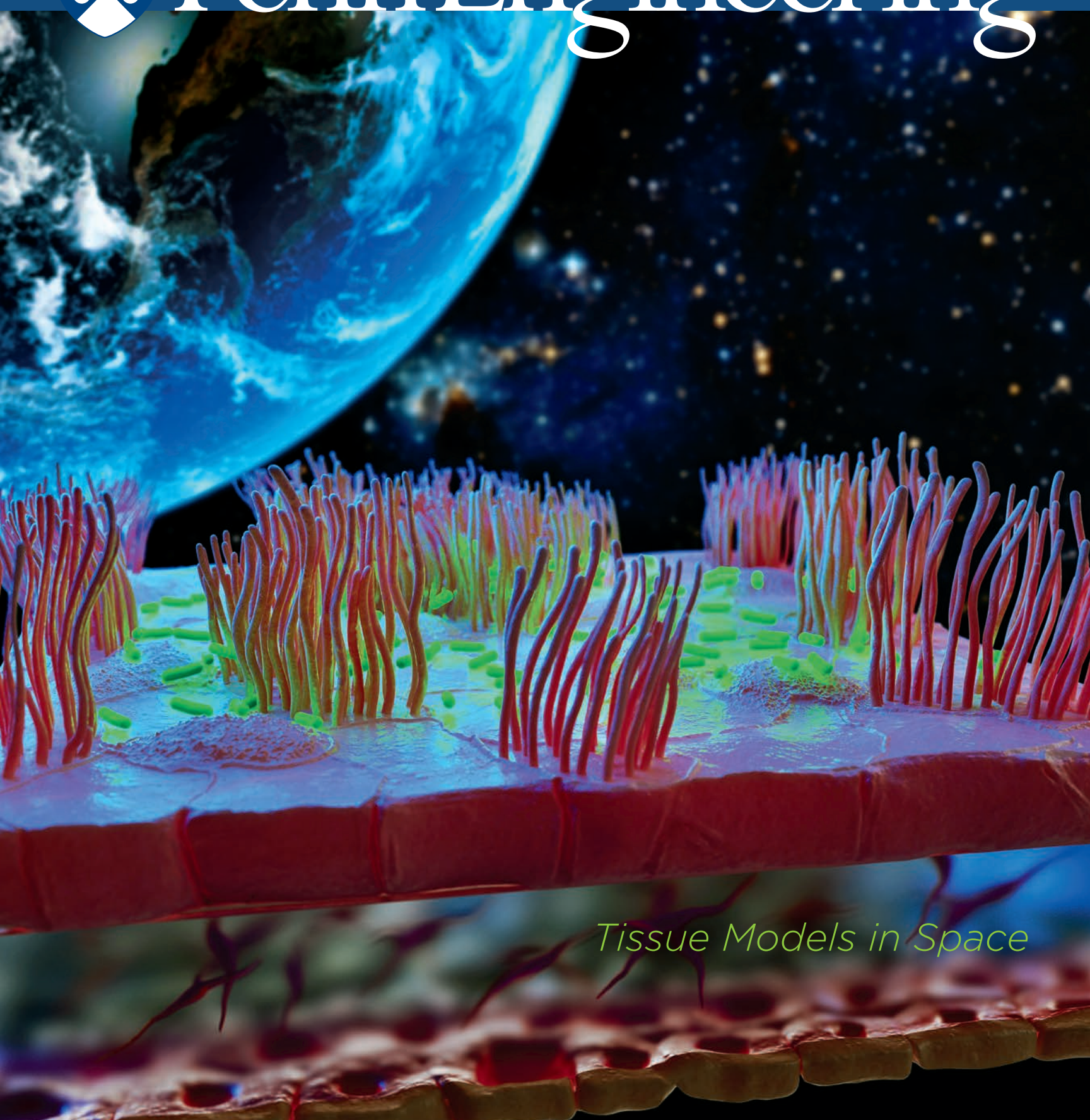




Penn Engineering



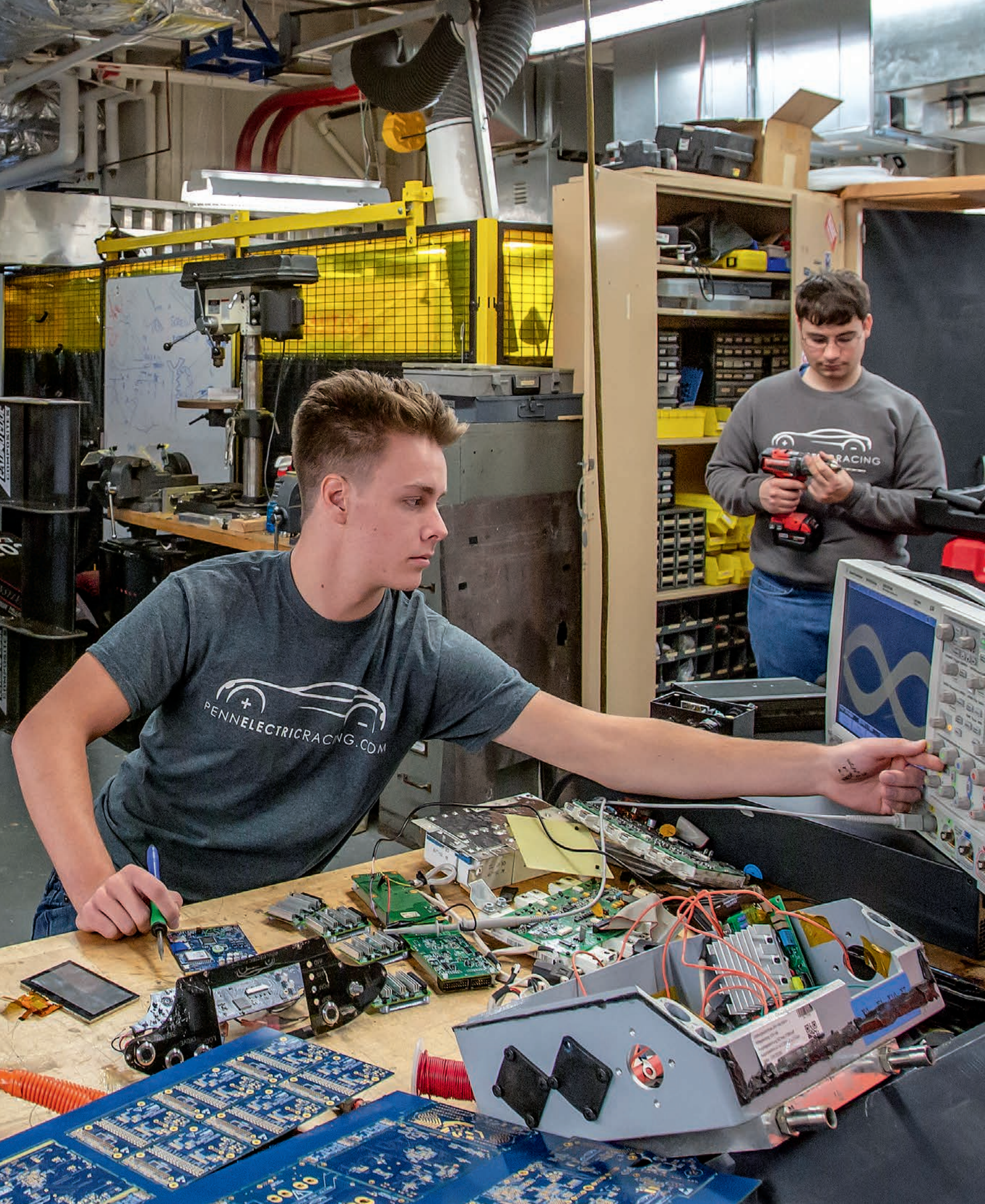
Tissue Models in Space

Driving Innovation

Penn Electric Racing traces its roots to solar-powered cars built on campus in the late '80s and early '90s. These experimental vehicles weren't fast, but pushed the envelope in thinking about new ways to design automotive systems. As batteries and electric motors improved over the decades, so did performance: In the past five years, the student-run team has taken home 29 trophies in international racing competitions and set an American acceleration record.

With more than 100 members spanning all six Penn Engineering departments, Wharton and the College, Penn Electric Racing is not just a place for students to flex their mechanical and electrical engineering skills, but an opportunity to learn, teach and mentor the next generation of envelope pushers.





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CONTENT

Penn Engineering / Fall 2018
University of Pennsylvania
School of Engineering and Applied Science

ON THE COVER

BEING IN SPACE SUPPRESSES ASTRONAUTS' IMMUNE SYSTEMS AND RENDERS THEM MORE PRONE TO INFECTIONS. TO HELP ADDRESS THIS, PROFESSORS DAN HUH AND SCOTT WORTHEN ARE SENDING MINIATURE, CELLULARIZED TISSUE MODELS TO THE INTERNATIONAL SPACE STATION AND INFECTING THEM WITH GREEN FLUORESCENT BACTERIA TO OBSERVE DIFFERENCES BETWEEN IMMUNE RESPONSES IN SPACE AND HERE ON EARTH.

Penn Engineering Magazine

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4

RISE OF ROBOGAMI

Cynthia Sung democratizes the building of customized robots by creating design software and manufacturing tools for the lay user.

8

MCIT ONLINE

Penn Engineering launches the Master of Computer and Information Technology Online, a transformational, first-of-its-kind Ivy League degree.

11

LEADERSHIP AND INSPIRATION

Bringing student voices to the administration, members of the Engineering Deans' Advisory Board offer a thoughtful blueprint for future projects.

14

TISSUE MODELS AT THE FINAL FRONTIER

Dongeun (Dan) Huh is creating "tissues on chips" to explore immune responses of the human respiratory system at the International Space Station.

18

ON OUR CAMERA ROLL

Images of Penn Engineering students, faculty and campus life.

20

TRANSLATING THE WORLD'S LANGUAGES

Chris Callison-Burch unlocks communication by using artificial intelligence to expand computerized translation capabilities.

24

CATCHING THE NEXT WAVE OF TECHNOLOGY

Alumnus and entrepreneur David Quattrone (M&T'96) is a co-founder of Cvent, a leading online platform in corporate meeting and event management.

32

Q&A WITH ALEX STERN

Penn Engineering Overseer Alex Stern (ENG'89, WG'94) credits his alma mater for the analytical framework he uses to solve problems.



VIJAY KUMAR
Nemirovsky Family Dean


Redefining the University

In a fast-changing technological landscape, where a degree can be outpaced by the inexorable, exponential advances in technology, planting the seeds for lifelong learning is an essential and fundamental element of education. Technology, along with an increasingly global marketplace and a demand for twenty-first century skills require reckoning with the traditional model of learning, both in pace and place.

The traditional “brick and mortar” college campus places stringent restrictions on space and time, making it difficult for us to focus on true *inclusion*, a key tenet of the *Penn Compact 2020*. Access to our high-caliber programs has had to be limited because of constraints on physical space and classroom and laboratory scheduling. Lifelong learning, which is increasingly important in our fast-paced world, is not feasible if we require professionals to stop mid-career to augment their education in a residential program. To address this, Penn Engineering has done what engineers do best: innovate and use technology to solve problems. Innovation in online learning has

enabled us to lower the barrier to entry to our programs, increasing inclusivity while maintaining high quality.

We are expanding learning opportunities and the educational footprint of Penn Engineering by offering free courses online in statistics and networked life, and modestly priced online modules leading to certificates in Robotics and in Software Engineering. In this issue you can read about a new online program, which will confer the Master of Computer and Information Technology (MCIT) at one-third the cost of our residential master’s program.

A university’s commitment to its students cannot be limited to the time they are enrolled in a single degree program. The future is one where students, no matter their stage of life, will have myriad options for learning at their fingertips. It is up to top-tier institutions like ours to ensure that these learners have access to excellence in every educational format and to continue attracting, retaining and educating the best and brightest. 

Rise of Robogami

THE DEMOCRATIZATION OF ROBOTICS

As the number of makerspaces across the world continues to grow, machines that cost up to hundreds of thousands of dollars a generation ago, like 3D printers and laser cutters, are becoming widely accessible and inexpensive. The trend has opened up endless new possibilities for the lay public to build and create. But there's still a big hurdle for would-be inventors to overcome: In order to make something new and useful like a customized robot, you still have to have the skills to design it, which can involve years of learning and background knowledge. As a result, there's a huge gap where the average person stops and a roboticist begins.

"Designing and making a robot has a lot of steps. First you have to come up with a design. Then you need the engineering knowledge to check that design. And you still need to learn the software to draw up the design. Only after all of that can you fabricate and test it," says Cynthia Sung, assistant professor in Mechanical Engineering and Applied Mechanics at Penn Engineering.

Sung wants to change that imbalance. She's working on tools for lay users that can democratize not only manufacturing, but also the basic elements of design—software that can work alongside nonexperts, providing engineering skills to fill any gaps in their knowledge.

The program she's created, "Interactive Robogami," is a computerized design tool that lets users build a virtual robot out of a library of basic body shapes,



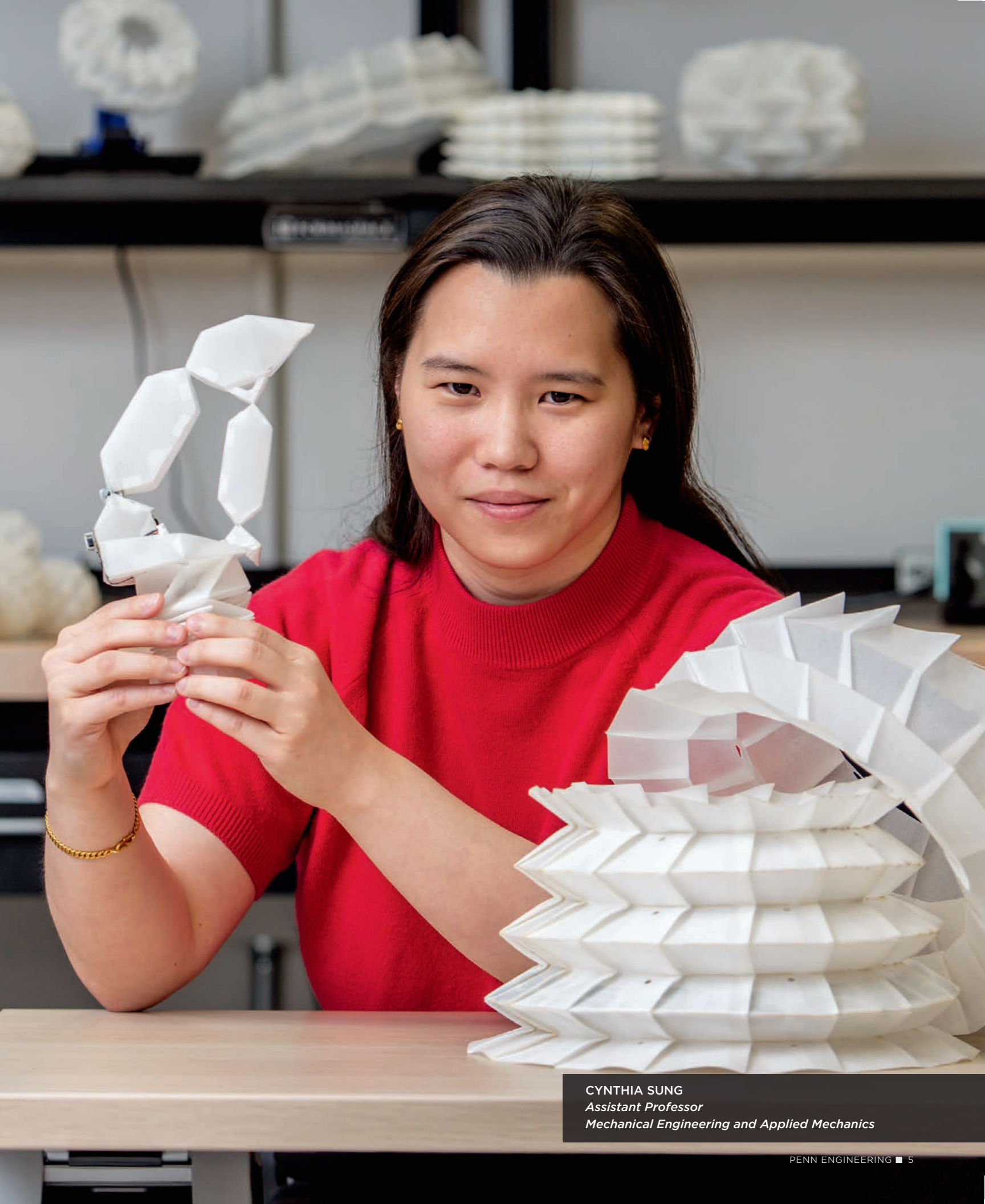
legs and wheels. Each component can be customized and arranged in any way a user wants, and when they're done, the software will simulate their creation's movements, its center of gravity and how it propels itself through the world. It's a playful, iterative process, a bit like tinkering with LEGOs. But under the surface, Interactive Robogami is much more than just a toy.

"With existing design tools, most people spend a lot of time trying to understand how to use the software. Then they have to learn engineering to figure out what to design," says Sung. "Interactive Robogami lets us combine those steps and make them more intuitive." In other words, she adds, it lets humans and machines cooperate on the design process. Users supply the creativity; the computer supplies engineering principles to back it up, and it can make suggestions on the design process accordingly.

**INTERACTIVE ROBOGAMI IS A
COMPUTERIZED DESIGN TOOL
THAT LETS USERS BUILD A VIRTUAL
ROBOT OUT OF A LIBRARY OF BASIC
BODY SHAPES, LEGS AND WHEELS.**

The tool also comes with another innovative feature. In addition to helping users in the design phase, the software also makes fabrication simple. The blocky, geometric shapes it generates aren't accidental. Those forms allow the software to project a robot's body into two dimensions, which users can then fabricate and fold into a 3D shape.

"It's origami; you can cut the basic shapes out by hand if you don't have a 3D printer or laser cutter. That means you can make the same robot out of cardboard, plastic, metal or pretty much any other foldable material. It lets us reach a much broader audience," Sung says.



CYNTHIA SUNG
Assistant Professor
Mechanical Engineering and Applied Mechanics



One of the appeals of Robogami is the ability to rapidly iterate. Ideas mocked up in a computer program can quickly be turned into working prototypes. Here, Sung discusses the sequence for a new design with doctoral student Jessica McWilliams and MEAM senior Andres Zambrano.

RETHINKING JOINTS

Sung's interest in origami goes back to childhood. As a young girl, her mother taught her to fold cranes, a classic origami shape. Watching paper take on new properties as it became a 3D object fascinated her, and eventually led her to study the mathematics behind it in high school and college. That's when it dawned on her that it could be a powerful tool for robotics.

"Just like folding a crane, a single sheet of material can become whatever structure you want. If you cut the sheet and fold it in different ways, you can get robots that look and move however you want, so you don't have to build extra parts," she says.

AS TRADITIONAL ROBOTS BECOME INCREASINGLY SMALL AND COMPACT, BUILDING JOINTS, HINGES AND OTHER MOVABLE PARTS BECOMES A MAJOR ENGINEERING CHALLENGE, DRIVING UP PRICE AND COMPLEXITY.

A perfect example of this, Sung notes, is a lowly hinge. The metal ones holding your front door together serve a useful purpose, but are relatively complex to make. Each one has at least three metal parts (two sides and an axle), all of which have to fit precisely into the others for the door to swing open.

"However, if you take a piece of paper and you just fold it once, that's a hinge. All the complexity of those three metal pieces with an axle down the middle goes away because the action of the hinge is embedded in the fold itself," Sung says. "You can extrapolate that idea to form complex joints. Pretty much every joint can be broken down into a series of hinges. If you arrange them in the right way, you can get a huge range of motion."

That's useful in any robotics application, but it's especially handy when it comes to miniaturization. As robots become increasingly small and compact, building joints, hinges and other parts becomes a major engineering challenge, driving up price and complexity. Robogami techniques, however, would let users fold them into shape from a single material, easing the fabrication process.

Sung is also working with materials that can fold themselves. By cutting tiny robotic forms out of materials that are heat sensitive, she's been able to make shapes that curl up at specific points when exposed to hot air or water. In the future, that could make it simple to create small robots quickly. "You'd design a robot using interactive tools, print it out and bake it, and your robot could potentially walk out of the oven," she says.

WORKING ACROSS FIELDS

Sung is quick to note that it'll be a while before this technique can be used to create actual working robots. At the moment, it's still experimental, but it represents an interdisciplinary way of thinking that she encourages in all her students.

"One of the students in my lab took a class in fluid dynamics and became very interested in the subject. He's now studying and characterizing the hydrodynamics of some origami patterns that may one day become underwater robots. That was totally unexpected. I never thought we'd be looking at how much drag an origami shape experiences," she says.

It's a perfect example of how experimenting with robots, especially foldable ones, means going beyond the boundaries of a single field and applying skills from seemingly unrelated areas.

As robots become more ubiquitous in the future, Sung notes, the ability to apply that level of creativity to them will be key to democratizing their use. Imagine one day being able to whip up a quick robot to help you clean a hard-to-reach storm drain, or to just entertain your cat while you're away for a weekend. With the right design and fabrication tools, the idea isn't so far-fetched.

"Right now, the technology isn't there to help people build these one-off robots," Sung says, "but design software like Interactive Robogami lets you intuit what design changes mean in the real world instead of using equations." In other words, she says, it could remove some of the last major hurdles for makers so their creativity can flow freely, bringing a future of lay robotics one step closer to reality. 🍷

By David Levin

MCIT Online

EXPANDING ACCESS TO COMPUTER SCIENCE

Just a generation ago, those with advanced computing skills tended to be confined to IT and other siloed professions. But with the advancement of computing systems and their integration into seemingly unrelated areas, today nearly every career and job function requires an understanding of how to design, use or manage computerized, digital and automated systems.

While children are now learning the basics of coding and data synthesis in school, it's a different story for mid-career professionals. When they realize that computational thinking and digital literacy are essential to their careers, but that they lack the foundation in those areas, the future can seem daunting and uncertain.

"Without a background in computer science or associated technologies, people can feel stuck in career limbo," says Susan B. Davidson, Weiss Professor in the Department of Computer and Information Science (CIS). "They will often find that they can't jump into a traditional master's degree program in computer science because those can require a technical undergraduate background. They also can't stop working in order to go back to school full time to get that knowledge."

Seventeen years ago, Penn Engineering addressed these issues and introduced the Master of Computer and Information Technology (MCIT) program, a master's degree with no computer science prerequisites designed specifically for mid-career professionals with undergraduate degrees outside of computer science. But many people have been unable to take advantage of the on-campus degree program because of distance, cost or time constraints. To meet that need, Penn Engineering recently launched MCIT Online, which is set to matriculate its first cohort of students in January 2019.





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Professors Susan Davidson and Chris Murphy videotape a lecture on computational thinking for MCIT Online.

A GAME CHANGER

The new MCIT Online program is the first completely online master's degree offered by the School of Engineering and Applied Science, and it is the only online Ivy League master's degree in computer science designed for students without computer science backgrounds. "We're excited for this program to allow people from around the world who have no computer science experience to rise up to a graduate knowledge level as quickly as possible, building on their experience, increased drive and maturity as adults," says Davidson.

It's also a program designed to fill a knowledge gap across industries. "Technology and computing are pervasive in business, science and society," says Chris Murphy, associate professor of practice in CIS and co-director of MCIT Online. "By offering the MCIT Online degree, we are helping people in fields such as education, healthcare, social work, government and urban development to increase their impact on solving many of the world's major problems through computing."

Like the campus-based program, MCIT Online is a game changer for students because it allows them to gradually adapt to the changing demands of their jobs and the job market. "Students can use the program to move into more interesting positions in their existing jobs, or make career moves that bring increased opportunities," says Davidson.

PRACTICAL AND RIGOROUS

With all of the interest the program has generated since its launch, MCIT Online will likely matriculate a first cohort that will be larger than its on-campus counterpart. While the program will include elements of self-pacing, such as allowing students to access lectures at night or on mobile devices, the curriculum of six required courses and four electives is as challenging as the on-campus program.

The program's courses will be taught by the same faculty members who teach in the on-campus degree. Students will work on assignments using a variety of programming languages (Python, C, SQL, Java), data analytics tools (Hadoop, TensorFlow) and computing environments (Linux, Amazon Cloud). Evaluations will test in-depth knowledge, and the same individual attention given to students on campus will be offered to online students via active discussion forums and video office hours with faculty and teaching assistants.

"This degree experience will be significantly more interactive than traditional distance learning," explains Sampath Kannan, Henry Salvatori Professor in CIS and co-director of MCIT Online. "Courses will have the same depth and rigor as traditional on-campus courses, with a blend of both computer science theory and applied, project-based learning."

MCIT ONLINE IS A GAME CHANGER FOR STUDENTS BECAUSE IT ALLOWS THEM TO GRADUALLY ADAPT TO THE CHANGING DEMANDS OF THEIR JOBS AND THE JOB MARKET.

Students can look forward to learning how to build high-quality software as part of a team and gaining a fundamental understanding about programming so they can pick up new languages and new technologies. "Programming and software engineering are just one part of computer science," says Murphy. "We are focused on providing students with a strong foundation in all areas of computer science and not just a particular skill."

TRANSFORMATIONAL IMPACT

The MCIT Online degree is offered in partnership with Coursera, the online education company that partners with 170 of the world's top universities and industry leaders to offer courses, specializations and degrees. Penn has offered courses on Coursera for several years and also offers three online degree programs, including the Master of Health Care Innovation. By delivering the MCIT program electronically, the degree program is one-third of the cost of the on-campus degree, making this program much more accessible. "I'm excited at the prospect of reaching many, many more students and helping them discover the joy of computing," says Davidson.

Outcomes from the program are yet to be realized, of course. But MCIT Online rests on the strong foundation of the on-campus program that has produced graduates who have gone on to highly coveted roles in software development, product management and data science at Google, Facebook, Microsoft and Apple. "Now, we'll be able to see a broader impact on the world through computing because we can reach so many more talented people," says Murphy. 🍷

By Amy Biemiller



EDAB seniors Daphne Cheung and Johnathan Chen

Leadership and Inspiration

EDAB'S BLUEPRINT FOR ENGINEERING STUDENT LIFE

To undergraduates at a large university, the administration can seem like a mysterious, all-powerful entity, creating policy that affects their lives but doesn't always take into account the reality of their day-to-day experience. The Engineering Deans' Advisory Board (EDAB) was designed to bridge that gap and give students a platform to communicate with key decision makers.

"Having a means to create significant change was appealing to me," says Johnathan Chen, (ENG'19, W'19), board president and Electrical Engineering major who also leads the electrical subteam for Penn's award-winning Electric Racing team. "From my first meeting during freshman year, I was

impressed with the professional comportment of the board's executive leadership. I could see how they were creating an important dialogue between students and the administration and I wanted to get involved."

The 13-member board meets once per week for 60 to 90 minutes. The executive board, comprised of four members, also meets weekly to plan out action items and brainstorm. Throughout his interactions with the group, Chen has found a real kinship with his fellow board members, who he says work hard and enjoy one another's company in equal measure.



Bioengineering major Daphne Cheung (ENG'19) joined the board as a first-year student because she saw an opportunity to develop professional skills outside of the classroom. "For me, it was about trying to build a different kind of aptitude in areas such as project management, and learning how to work with different kinds of people, including students and faculty, and of course, the deans," she says.

Currently, Cheung handles recruitment and onboarding for new members as vice president. "There's a real satisfaction in knowing we play such an important role in connecting students to the administration and making previously unknown concerns heard," she says.

PROBLEMS AND SOLUTIONS

Most recently, the board researched, culled and presented a 57-page white paper that detailed students' greatest concerns, from mental health stressors to club engagement to pre-professional opportunities. This process occurs every four years, but this year's edition was especially ambitious in scope, tackling big issues such as financial aid and diversity and inclusion.

"The document included everything we wanted the deans to know about us and it also created a blueprint for our future projects," Chen says.

For the deans, the white paper set a tone, signaling that these students take their responsibility seriously.

"EDAB board members are organized, thoughtful and think strategically to implement initiatives that benefit the School," says Vijay Kumar, Nemirovsky Family Dean of Penn Engineering. "The dedication with which they carry out their mission of bringing student voices to the deans is inspiring. I am amazed by the enormous maturity and expertise that belies the age and experience of these students."

Cheung has gotten particularly involved in broadening pre-professional opportunities for students. "We noticed that there was a disproportionate representation of finance and consulting companies on campus, but not as many for students hoping to enter biotech, industry, manufacturing and product design. The process of getting companies on campus was complex, so we sought a shorter-term solution. We worked with Career Services to identify areas of improvement, and set up advising hours so students could seek help and get the answers they needed much more easily and quickly," she says.

Another example of a larger-scale effort is a recent mental health peer audit of undergraduate students in order to open up a conversation with the goal of ascertaining what exactly is at the core of their stress.



EDAB members regularly discuss their conversations with the deans, sharing their thoughts on the academic and co-curricular culture of Penn Engineering.

Still other board projects have included discrete, material improvements such as establishing a photo studio for students to document their projects and expanding study room options. When Chen first joined EDAB, he immediately suggested the group look into improving signage around campus. “In the first few weeks I was here I got lost all the time. That seemed like a simple thing that, once you called someone’s attention to it, could be improved,” he says.

One of the board’s most recent, tangible accomplishments, Chen says, has been to create a social space for students. “In Penn Engineering, social opportunities have traditionally existed within majors through shared classes. We felt that creating a physical space to encourage social interaction across study disciplines would only benefit students and enrich their social and academic lives.” The board worked with the administration to get furniture placed in the Levine lobby to activate that space for casual student use.

NETWORK OF LEADERS

Given that many student life and academic issues transcend Penn Engineering, EDAB interfaces with other similar organizations across the University. “We’re involved in the admissions advisory boards, and we meet with both the Wharton and SAS

versions of our group,” Cheung says. “An academic steering meeting has included representatives from boards across the University. Bureaucracy can be very daunting to navigate at times, but we find that when we work together we can get things done.”

They’ve also met with the dean of Penn Admissions, Eric Furda, faculty across the University and the Wharton dean. “We learn what’s on the faculty’s minds,” Cheung says. “Realizing that they sometimes face the same problems we do when trying to effect change is eye-opening.”

In preparation for the 2018-19 academic year, EDAB’s leadership team spent time reflecting on what lies ahead and how it can best evolve as it recruits new members. For instance, the board itself has changed to better represent the student body, which has become increasingly female. For everyone involved, the challenges come with their own lessons and learnings.

“Being involved in EDAB has helped me to become more comfortable with public speaking and, in particular, addressing people with power,” Cheung says. “It’s also helped me work with others, to become a better listener, to negotiate different points of view and find common ground. It’s an awesome responsibility and a great privilege.”

By Elisa Ludwig

Taking Tissue Models to the Final Frontier

Some may think of outer space as a sterile environment, but infections are a common occurrence aboard spacecraft, where exposure to microgravity negatively affects immune system function. For example, about half of the astronauts who flew in Apollo missions reported minor bacterial or viral infections within a week of their return. Although data for U.S. missions are limited, 26 instances of infection were reported for American astronauts from April 1989 to January 1998.

Space flight is likely to cause deleterious changes to the composition of bacterial flora, leading to an increased risk of infection. The environment may also affect the susceptibility of microorganisms within the spacecraft to antibiotics, key components of flown medical kits, and may modify the virulence of bacteria and other microorganisms that contaminate the fabric of the International Space Station and other flight platforms.

THE TEAM LED BY HUH AND WORTHEN AIMS TO MODEL RESPIRATORY INFECTION, WHICH ACCOUNTS FOR MORE THAN 30 PERCENT OF ALL INFECTIONS AFFECTING ASTRONAUTS.

“It has been known since the early days of human space flight that astronauts are more prone to infection,” says Dongeun (Dan) Huh, Wilf Family Term Assistant Professor in Bioengineering at Penn Engineering. “Infections can potentially be a serious threat to astronauts, but we don’t have a good fundamental understanding of how the microgravity environment changes the way our immune system reacts to pathogens.”

In collaboration with G. Scott Worthen, a physician-scientist in neonatology at the Children’s Hospital of Philadelphia, Huh will attempt to answer this question by sending tissues-on-chips to space. Last June, the

Center for the Advancement of Science in Space (CASIS) and the National Center for Advancing Translational Sciences (NCATS), part of the National Institutes of Health (NIH), announced that the duo had received funding to study lung host defense in microgravity at the International Space Station.

Huh and Worthen aim to model respiratory infection, which accounts for more than 30 percent of all infections reported in astronauts. The project’s goals are to test engineered systems that model the airway and bone marrow, a critical organ in the immune system responsible for generating white blood cells, and to combine the models to emulate and understand the integrated immune responses of the human respiratory system in microgravity.

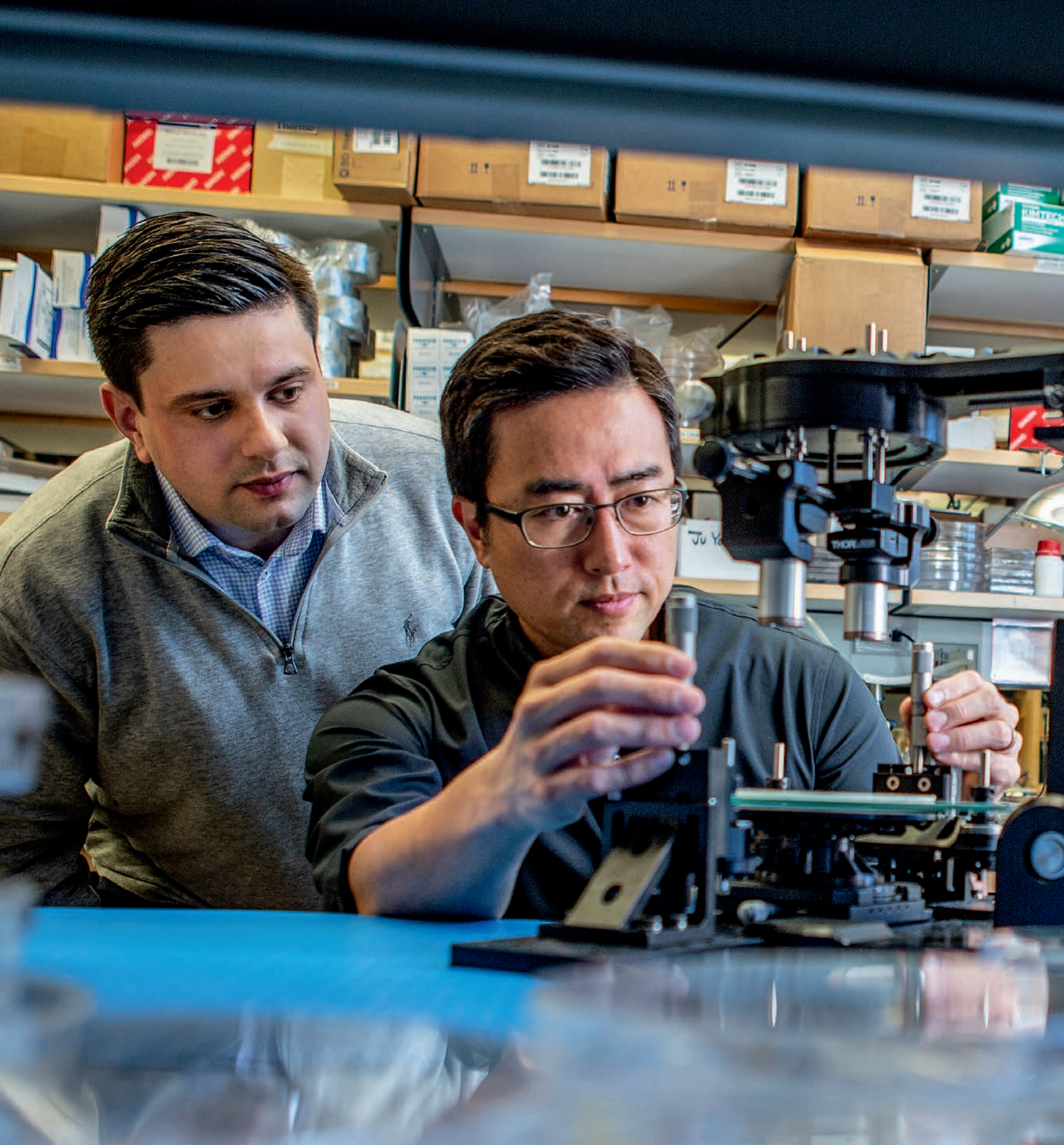
With the initial launch aboard a Cygnus NG-11 rocket scheduled for April 2019, the first phase of the project will focus on simulating infection separately on chips containing lung and bone marrow tissue. If successful, the team will integrate the two devices, which would be launched into space two years later. “Ultimately, if we find abnormalities in how the tissues respond to infection, we might be able to come up with intervention strategies that would inhibit or minimize adverse effects of microgravity,” Huh says.

CAPTURING COMPLEXITY

The idea of creating microengineered models of the human lung arose when Huh was a Wyss Technology Development Fellow at the Wyss Institute for Biologically Inspired Engineering at Harvard University. In 2010, his study led to a prestigious publication in the journal *Science*. The article described a lung-on-a-chip that mimicked the air-blood interface between an alveolar air sac and small blood vessels called capillaries. The device was integrated with a computer-controlled vacuum to produce cyclic stretching of the tissue-tissue interface to simulate breathing movements.



Containing living human cells, the Huh lab's tissue-on-a-chip systems allow for in vivo experiments that would not otherwise be possible.



Professor Dan Huh and doctoral student Andrei Georgescu assemble a precise, multilayer tissue model for drug screening.

“We demonstrated for the first time that a microengineered system could mimic complex organ-level functions in the lung such as immune responses to bacteria, toxins and environmental particulates,” Huh says. “This generated a lot of excitement in the field and stimulated a collective effort to develop more physiologically relevant *in vitro* models using micro-engineering technologies.”

Standard *in vitro* systems, which consist of cells grown in static culture media in hard, flat plastic dishes, are rudimentary and do not represent the complexity of the human body. Meanwhile, animal models often do not replicate disease-related processes in humans because of species-specific differences. As a result, approximately 90 percent of drugs that enter clinical trials ultimately fail due to safety or efficacy concerns, costing the pharmaceutical industry more than a decade of research and several billions of dollars per drug candidate.

Unlike traditional systems, 3D organs-on-chips capture the architecture and cellular heterogeneity of tissues found in human organs and mimic the dynamic mechanical and biochemical processes of the surrounding environment. And unlike animal models, they are composed of human cells and are amenable to real-time visual analysis of drug responses. According to unofficial feedback from high-level NIH employees, the *Science* study changed the way that they thought about *in vitro* testing. Recognizing the potential of the approach, NCATS launched the Tissue Chip for Drug Screening program in 2012.

Since the seminal study in 2010, Huh and his collaborators have made tremendous progress, developing organ-on-a-chip models for the eyes, gut, placenta, cervix and pancreas to study conditions such as dry eye disease, Crohn’s disease, preterm birth and diabetes. Last June, the Cancer Research Institute announced that Huh received its inaugural Technology Impact Award of \$1 million to use microchips to study interactions between cancer and immune cells for the development of immunotherapies.

CHALLENGES ABOVE EARTH

Conducting experiments on Earth is hard enough, but space presents an additional layer of unique challenges. To overcome these hurdles, Huh and Worthen are teaming up with two microgravity research companies called SpacePharma and Space Tango. These implementation partners will be intimately involved in the development of the

tissues-on-chips in a space-ready fashion, and in the establishment of remote control and real-time data recovery from the International Space Station.

A major challenge will be to execute several complex experimental steps to infect the cells with microorganisms and monitor their responses for the entire duration of the flight. To address this concern, the team is working closely with their implementation partners to develop a fully automated cell-culture platform with imaging capabilities.

CONDUCTING EXPERIMENTS ON EARTH IS HARD ENOUGH, BUT SPACE PRESENTS AN ADDITIONAL LAYER OF UNIQUE CHALLENGES.

If all goes according to plan, the researchers will analyze cytokines, chemokines and other immune molecules secreted by an airway-on-a-chip infected with *Pseudomonas aeruginosa* bacteria, which can cause severe illness and even death in humans. The bone-marrow-on-a-chip will be used to simulate the mobilization of immune cells called neutrophils, which are among the first responders that travel from the bone marrow to the site of an infection. Meanwhile, control experiments will take place in a terrestrial facility.

“We can visualize how the lung cells natively slow down and block bacteria by secreting more mucus, and most exciting, we can measure how systemic signaling molecules released by the airway cells recruit white blood cells from the bone marrow by stimulating them to enter the bloodstream and find their way to the infected tissue,” says third-year doctoral student Andrei Georgescu. “By sending these organ-modeling chips to the Space Station while also mirroring the experiments down here on Earth, we’ll be able to closely compare differences and understand changes in the behavior of human cells and pathogenic bacteria during an infection.”

The four other “Chips in Space” research projects funded by CASIS and NCATS will examine human physiology and disease aboard the International Space Station. “This collective effort could make a huge impact on the health of astronauts during and after space flight,” Huh says. “We hope that the lessons we learn will better prepare astronauts to fight sickness as they explore the next frontier.”

By Janelle Weaver



On Our Camera Roll



1. Seniors in Computer and Information Science and in Networked and Social Systems Engineering gather in the conference room at 3401 Walnut Street.
2. Bowen Yang, a master's student in Computer Graphics and Game Technology, reviews a program in the SIG Center for Computer Graphics.
3. MEAM senior Karina Gunadi solders a potentiometer that will control a robot's actuators.
4. Computer and Information Science Professor Lyle Unger lectures in Heilmeier Hall.
5. Graduate students Alexander Corbisiero and Danielle Rossi use electromyographic signals (EMG) to control a motor.



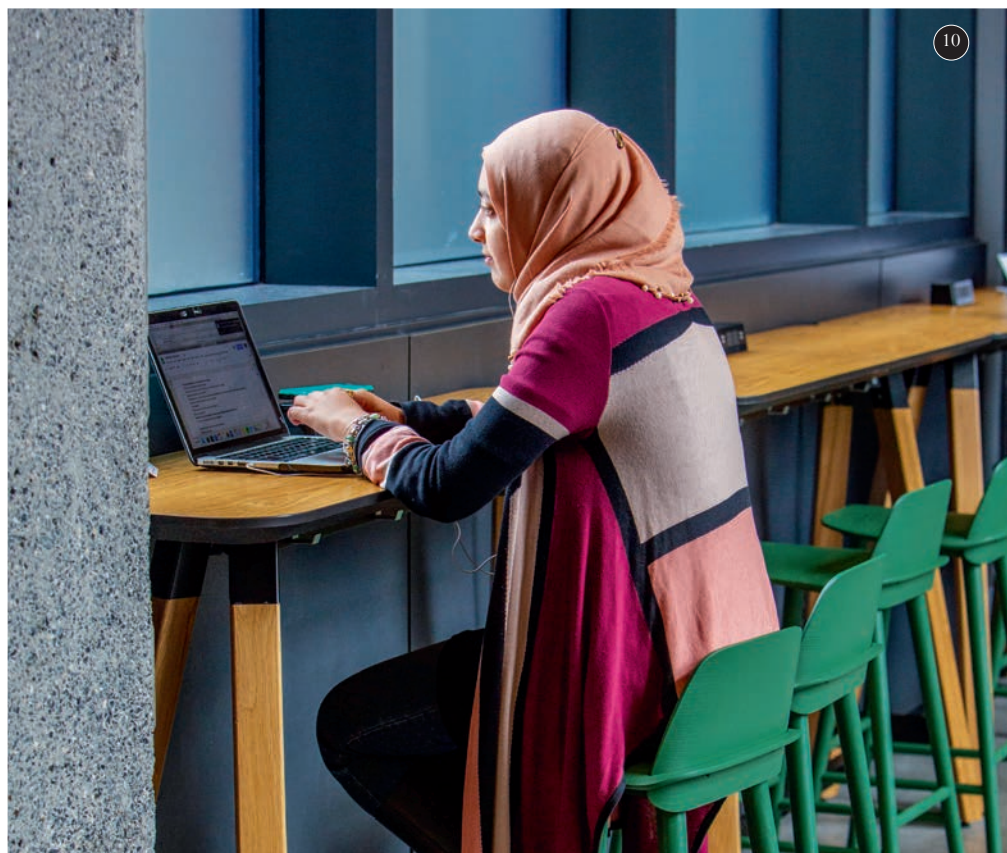
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6. Doctoral students Mikhail Hayhoe and Cassiano Becker, members of the Preciado lab, discuss modeling the brain and its response to external stimuli. **7.** Leveraging time between classes, undergraduates take a moment for conversation in the Accenture Café. **8.** Lines of bicycles outside the Towne Building reveal the number of students who choose a “green” ride to campus. **9.** Wilfredo Méndez, doctoral student in the Stebe lab, examines microfluidic device features for continuous membrane formation. **10.** A student enjoys a quiet study space in Skirkanich Hall.

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TRANSLATING THE WORLD'S LANGUAGES

Chris Callison-Burch first wondered how computers could be used to translate languages as a high school freshman while tinkering with his first computer and reading science fiction. Classics such as *The Hitchhiker's Guide to the Galaxy* featured creative linguistic plot devices like "Babel fish," which when stuffed in an ear allowed instant comprehension of any language.

"Opening up communication between all people is still really my goal," says Callison-Burch, laughing at the improbable scope of his now decades-long ambition, which he's uniquely equipped to pursue.

OVERCOMING OBSTACLES

Known for his knack for addressing bottlenecks and obstacles to advance computerized translation performance, Callison-Burch works at the intersection of linguistics and the computer science field of machine learning, using artificial intelligence to automatically learn from experience. An associate

professor in Computer and Information Science, Callison-Burch similarly strives to lower barriers to entry for students interested in computer science and to research topics that benefit human welfare and dignity.

CALLISON-BURCH WORKS AT THE INTERSECTION OF LINGUISTICS AND THE FIELD OF MACHINE LEARNING, USING ARTIFICIAL INTELLIGENCE TO AUTOMATICALLY LEARN FROM EXPERIENCE.

"What drew me to the field of computational linguistics was that if you could make this technology work, then the value in terms of society, economics, culture and understanding would be huge," he says, noting real-time translation's value for global

1.0253597

dichotomy

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reasonings

1.0002848

0.99977845

inferences



CHRIS CALLISON-BURCH
Associate Professor, Computer and Information Science

security, commerce and disaster recovery. For example, many people affected by Haiti’s 2010 earthquake texted requests for help in Haitian Creole, yet because so few first responders knew the language, critically needed assistance was delayed and thousands of people ultimately died.

“My research is guided by trying to address languages that haven’t yet made it into Google Translate,” Callison-Burch says. His research group has developed novel cost- and time-saving methods to translate languages using crowdsourcing and images, breakthroughs first published in 2011 and 2018, respectively. These methods offer great promise for generating translations beyond the current set of 100 languages on Google Translate, potentially expanding to even more of the world’s known 7,000-plus languages.

“Chris is a top influencer in our field who has changed how we do things for machine translation research,” says Kevin Duh, senior research scientist

at the Johns Hopkins University Human Language Technology Center of Excellence. “Whenever we need to build a new machine translation system, we follow his procedure of collecting data from the Amazon Mechanical Turk, hiring workers via this global marketplace for crowdsourced labor. His use of the wisdom of the crowd as applied to translation gives us a way to get better results quicker with fewer resources.”

ENGINEERED DICTIONARIES

In 2018, Callison-Burch’s research group shared another promising new translation method for some of the world’s most difficult-to-translate languages. They used images (for instance, of a cat) plus vast quantities of crowdsourced data identifying linked words for each image to create reverse-engineered dictionaries for 10,000 words in 100 languages. “We’re building on an insight that images are somehow interlingual, that an image of a cat is the same whether you speak English or Indonesian, so



Callison-Burch's work at the intersection of linguistics and artificial intelligence has also led to a project where computers automatically parse news articles for statistics on gun violence.

we can use simplified representations of images to train the model,” says Callison-Burch. “This language-independent way of thinking about words through their visual representations allows us to use a new type of data to learn translations.”

Even though Google Translate is as close as possible to the state of the art for 100 languages, the quality is wildly different between languages like French and Arabic, and languages like Indonesian and Urdu. Callison-Burch’s “Massively Multilingual Image Dataset,” published in the *Proceedings of the Association for Computational Linguistics* (ACL), addresses crucial gaps in machine learning translation techniques. Prior methods required costly data from professional translators and vast quantities of online texts such as websites, books and newspapers. This approach worked for the 24 “high-resource” languages of the European Union but wasn’t useful for “low-resource” languages with fewer speakers, sparse or nonexistent translation budgets, and scarce language texts online.

Daphne Ippolito, doctoral student and ACL paper first co-author, describes the image data set “as an interesting and necessary step that allows us to stop relying on experts for translation and to try to gather our data from whomever and wherever we can. The paper further shows that our algorithms tend to work better for translating words that are more concrete such as ‘house’ or ‘sailing’ regardless of their part of speech.”

THE LANGUAGE-INDEPENDENT WAY OF THINKING ABOUT WORDS THROUGH VISUAL REPRESENTATIONS ALLOWS CALLISON-BURCH TO USE A NEW TYPE OF DATA TO LEARN TRANSLATIONS.

John Hewitt (CIS’18), also first co-author, says, “We released the data and code because the paper provides proof of concept that methods using visual information can be useful for low-resource languages. It provides the first data set for researchers to explore the utility of visual symbol representation at a large scale, allowing others to improve upon the methods we’ve developed.”

Derry Wijaya, who grew up in Malang, Indonesia, and is now an assistant professor at Boston

University, joined Callison-Burch’s group as a postdoc in 2016. “My Ph.D. advisor gave me a list of people who were doing out-of-the-box research that is fun, exciting and at the same time has big impact for natural language processing,” says Wijaya. “Chris was first on that list. He taught me how to navigate my first academic career negotiation and placement.” She appreciates how Callison-Burch helped her develop skills in advising students and writing grants, and how he guided her and other early-career faculty as they submitted a grant that helped them develop visibility with a key funder, the Defense Advanced Research Project Agency (DARPA).

“Chris also helped me to adjust my communication style. I grew up in Javanese culture, which has a concept of self-restraint,” says Wijaya. “I’m now more direct in discussions about research, especially in giving others feedback. This helps me have more confidence, which is good.”

BEYOND EXPECTATIONS

Mindful of how his own undergraduate experiences launched his career, Callison-Burch encourages undergraduates to contribute to his research group. “Being open to anyone who wants to try out research has paid dividends that are wildly beyond my expectations,” says Callison-Burch. In 2017-2018, 40 undergraduates worked in his lab alongside eight graduate students and two postdocs. This fall he began teaching an AI course to a cohort of 100 students; 250 students were wait-listed, and he plans to expand the enrollment cap in the future.

Broader concerns inform his research as well. To address the risk that low-wage workers associated with Amazon Mechanical Turk might experience “digital sweatshop” conditions, Callison-Burch developed a Chrome plugin extension called Crowd Workers to help participants find higher-paying work. His group has a pending grant to explore ways to help people living in rural U.S. communities to develop skills to earn a living wage via Amazon Mechanical Turk.

Amid these broad goals Callison-Burch retains a humble perspective, ruefully admitting, “I’m embarrassingly monolingual for someone who works on translation. The machine has me beat; it’s much more capable of learning languages than I am.” 🍷

By Jessica Stein Diamond

David Quattrone

CATCHING THE NEXT WAVE OF TECHNOLOGY

David Quattrone (M&T'96) is the CTO and co-founder of a global event management software company that was born from scribbles on the back of a napkin. Known as a skilled problem solver for his clients, he jumped at the opportunity to help create Cvent, a leading platform in the event management and hospitality spheres.

"A stranger called me, and left this long, rambling message on my voicemail, saying a coworker had given him my name for a new business," Quattrone recalls. "When I finally met Reggie Aggarwal, I asked him for his business plan. He didn't quite have one at the time, but he had written it all down on a napkin."

QUATTRONE CAME TO PENN AT A TIME WHEN AMERICANS WERE BUYING THEIR FIRST COMPUTERS AND STUDENTS WERE GETTING THEIR FIRST UNIVERSITY EMAIL ADDRESSES.

Quattrone and Aggarwal both saw the need for a business that provided corporate-grade online tools to manage meetings and events. Shortly after their first meeting, the team founded Cvent in the fall of 1999, and since then, it has become

one of the largest providers of event management software in the world, with over 3,400 employees, 25,000 customers and 300,000 users worldwide. Quattrone has remained with the company throughout, overseeing its slow beginning, near-bankruptcy, regrowth, emergence on the public market, its 2016 sale to Vista Equity Partners (for a price of \$1.65 billion) and continued strong growth as part of the Vista portfolio.

AHEAD OF THE CURRENT

Quattrone came to the University of Pennsylvania at a time when Americans were buying their first computers and Penn students were getting their first university email addresses. "We really caught the wave in terms of timing as everything moved online," Quattrone says, "and my career followed that path. I went from one opportunity at the cusp of the wave to the next."

Quattrone studied Electrical Engineering and Economics as a student in the Jerome Fisher Program in Management & Technology (M&T). As a junior he founded the Network Resources Group, a web consulting firm, with two of his classmates at Penn Engineering. After graduation, he declined offers from large New York City banks in order to return to consulting with a Penn Engineering alumnus, Dwayne Sye (ENG'95), in Washington, D.C.



DAVID QUATTRONE (M&T'96)
CTO and Co-founder, Cvent

“I decided that working for a small company where I could drive growth was far more interesting than going up to New York and being a cog in the machine,” he states.

Quattrone’s entrepreneurial spirit was forged during his time in that early consulting space. Businesses were rushing to keep up with the rapid pace of new technology, and each day brought in clients from retail, banking, health care and government looking to make the leap online. When Aggarwal came to him in 1999, Quattrone embraced the opportunity and they asked both Sye and Chuck Ghoorah, a Duke-educated lawyer and close friend of Aggarwal, to join them at Cvent. Building and marketing a software so ahead of its time was the ultimate problem to be solved.

CVENT GREW SLOWLY AT FIRST AS CUSTOMERS ADAPTED TO THE NEW TECHNOLOGY, THEN RAPIDLY EXPANDED IN THE DOT-COM BOOM OF 2000, ATTRACTING OVER \$17 MILLION IN VENTURE CAPITAL.

“It’s hard to imagine today, but back then, email wasn’t a classy enough solution for business communications,” Quattrone laughs. “Clients were very reluctant to use our software. And when we explained to them that you didn’t buy our software, that you subscribed to it on an annual basis and it was delivered over the internet, they would think we were nuts.”


TURNING THE TIDE

Cvent grew slowly at first as customers adapted to the new technology, then rapidly expanded in the dot-com boom of 2000, attracting over \$17

million in venture capital. The company was about to undertake a massive expansion in 2001 when the bubble finally burst, pushing them nearly to bankruptcy and forcing the team to cut 80 percent of its staff.

“We weathered the storm because of our people,” Quattrone says. “The discipline that we had back then as a 25-person company continues to serve us well today across our global organization of more than 3,400 employees. We basically bootstrapped the firm and went back to the basics of creating a healthy long-term business: Hire the best people, invest in great products and focus on our customers’ needs and success. That time period formed the Cvent culture that still helps us to succeed today.”

Now, Quattrone keeps Cvent a leader in the event technology and hospitality space by developing software that covers the entire life cycle of an event, from inception, organization and registration to venue selection, content management and attendance tracking. His company has a network of loyal customers, including everyone from your local knitting association to Amazon Web Services, and now powers an entire ecosystem that connects organizations in need of locations to host their events with venues that offer compelling event spaces. Cvent is regularly named one of the best places to work by *The Washington Post*. Having remained with his company for over 18 years, Quattrone is inclined to agree.

“Every year there are new opportunities and new challenges for me,” he states. “There’s still a tremendous amount of opportunity in Cvent’s ability to drive innovation, and I think that’s the reason I’ve stayed with this company as long as I have. We believe there’s a lot of room moving forward.” 

By Emily Schalk

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DISTINGUISHED LECTURE SERIES



HAROLD PENDER AWARD LECTURE

Penn Engineering celebrated **Yann LeCun** as the 2018 recipient of the Harold Pender Award. LeCun, Vice President and Chief AI Scientist at Facebook, and the Silver Professor at the Courant Institute and the Center for Data Science, presented a lecture titled, “Could Machines Be More Like Humans?” to a standing-room-only crowd on September 19, 2018.

The Harold Pender Award, Penn Engineering’s highest honor, was established in 1972, and is given by the faculty of The Moore School to an outstanding member of the engineering profession who has achieved distinction by significant contributions to society.



THE POWER OF PENN

Dr. Vivek Shenoy, Eduardo D. Glandt President's Distinguished Professor, sat center stage in Boston to promote *The Power of Penn*, the University's landmark new capital campaign. His insights are improving our understanding of cellular disease and demonstrating how Penn Engineering applies knowledge to build a better future.

Dean Vijay Kumar has harnessed this energy with the launch of *The Power of Penn Engineering: Inventing the Future*, an ambitious campaign to raise \$170 million by June 2021. According to Dr. Kumar, "The campaign will capitalize on Penn Engineering's collaborative culture to catalyze technological innovation and solve the greatest challenges in our data- and information-driven world."

Fundraising priorities are focused on growing the number of outstanding faculty, building

revolutionary new spaces and increasing student opportunities through financial aid.

An astounding \$122 million has already been raised, creating 18 endowed faculty positions and resulting in a surge of new hires. In only three years, the number of tenured faculty has grown from 113 to 131, and put within striking distance the School's final goal of 150. What's more, a \$15 million gift from the A. James & Alice B. Clark Foundation, the largest contribution to undergraduate financial aid in Penn's history, has established a transformative new scholarship program at the School.

But there is still more to come. Dean Kumar remains "driven by the promise of all we can accomplish together, and grateful for the many ways our alumni and friends continue to power our success."

HONORS & AWARDS

Portonovo Ayyaswamy, *Asa Whitney Professor in Mechanical Engineering and Applied Mechanics*, has been named an American Society of Mechanical Engineers (ASME) Honorary Member “for exceptional contributions to mechanical engineering through a career marked with seminal and groundbreaking research scholarship, which has engendered transformational technology transfer for diverse applications; and for exemplary professional service to the worldwide scientific and practicing thermal engineering community.”

Danielle Bassett, *Eduardo D. Glandt Faculty Fellow and Associate Professor in Bioengineering*, is the recipient of the 2018 Erdős-Rényi Prize. The award, given by the Network Science Society, or NetSci, recognizes the achievements of a young researcher working in the field of network science.

Lee Bassett, *Assistant Professor in Electrical and Systems Engineering*, has been selected to participate in the National Academy of Engineering’s (NAE) 2018 U.S. Frontiers of Engineering Symposium. The nation’s brightest young engineers from industry, academia and government are nominated by fellow engineers or organizations to participate.

Liang Feng, *Assistant Professor in Materials Science and Engineering*, has been elected a fellow of the Optical Society. The scholarly society is the “world’s leading champion for optics and photonics, uniting and educating scientists, engineers, educators, technicians and business leaders worldwide to foster and promote technical and professional development.”

Deep Jariwala, *Assistant Professor in Electrical and Systems Engineering*, is the recipient of a Young Investigator Award from the journal *Nanomaterials* for his “impressive work combining novel nanomaterials, such as carbon nanotubes and 2D transition metal dichalcogenides, into heterostructures and electronic and optoelectronic devices.” Dr. Jariwala was also named to the *Nano Letters* Early Career Advisory Board.

Kenneth Laker, *Professor Emeritus in Electrical and Systems Engineering*, has been named to the IEEE Technical Activities Board Hall of Honor, which is designed to recognize those who have made major contributions to the IEEE, the world’s largest technical professional organization for the advancement of technology.



Portonovo Ayyaswamy



Danielle Bassett



Lee Bassett



Liang Feng



Deep Jariwala



Kenneth Laker



Chinedum Osuji



Michael Mitchell

Michael Mitchell, *Skirkanich Assistant Professor of Innovation in Bioengineering*, is the recipient of a \$2.4 million NIH Director's New Innovator Award, which is part of the NIH Common Fund's High-Risk, High-Reward Research program, which supports innovative research proposals that might not prove successful in the conventional peer-review process despite their potential to advance medicine.

Chinedum Osuji, *Eduardo D. Glandt Presidential Professor in Chemical and Biomolecular Engineering*, has been named a fellow of the American Physical Society (APS), which recognizes members who have made advances in knowledge through original research and publications or made significant and innovative contributions in the application of physics to science and technology.



Linh Thi Xuan Phan



Paris Perdikaris

Paris Perdikaris, *Assistant Professor in Mechanical Engineering and Applied Mechanics*, is the recipient of a five-year Early Career Award from the Department of Energy's Office of Advanced Scientific Computing Research to pursue a new approach to modeling complex and unpredictable physical systems.

Linh Thi Xuan Phan, *Assistant Professor in Computer and Information Science*, is the recipient of an NSF CAREER Award to further her research in developing new strategies to protect self-driving cars and other systems that exist in both the cyber and physical worlds from attack by intruders operating online.



Shu Yang



Kathleen J. Stebe

Kathleen J. Stebe, *Richer & Elizabeth Goodwin Professor in Chemical and Biomolecular Engineering and deputy dean for Research and Innovation in Penn Engineering*, is a recipient of the 2018 Langmuir Lectureship Award, presented by the American Chemical Society's Division of Colloid & Surface Chemistry and its journal, *Langmuir*, in recognition of individuals working in the interdisciplinary field of colloid and surface chemistry.

Shu Yang, *Professor in Materials Science and Engineering*, has been named a fellow of the American Physical Society (APS), which recognizes members who have made advances in knowledge through original research and publications or made significant and innovative contributions in the application of physics to science and technology.

Alex Stern

GLOBAL SCOPE AND INSIGHT



Overseer Alex Stern's influence on engineering's future reflects his integrative, collaborative and proactive sensibility. "To stay relevant, it's critical to constantly innovate and be forward-thinking," says Stern (ENG'89, WG'94). As Chief Operating Officer of Lazard Ltd, a global financial advisory and asset management firm, and Chief Executive Officer of its Financial Advisory business, Stern's workdays begin with catching up on world events and with colleagues in more than 25 countries.

"Fortunately, we have dedicated, knowledgeable teams in all the major markets who advise clients locally and who share local knowledge with me and relevant colleagues," he says. "It's gratifying to work with a group of highly intelligent, intellectually curious people to develop creative solutions with high impact. Our business is complex and so are our clients' challenges. In my line of work, it's always a team effort."

How has your Penn Engineering education influenced your career?

The analytical framework for problem solving that I learned at Penn has been invaluable because it addresses ways to solve complex real-world problems. This training becomes more useful all the time: As disruptive technologies drive changes in business models, companies' strategic challenges are increasingly multifaceted.

Which courses feel most relevant to challenges you face today?

There are interesting parallels between the computer and telecom networking classes I took at Penn and the work I do today. While Lazard is an advisory firm, it is also fundamentally a network of people, all of whom have broad networks of relationships. We're all interconnected on a global scale. As it turns out, those classes at Penn gave me a unique perspective on our operations.

As an Overseer, how do you hope to cultivate next-generation leaders?

One of the roles of the Overseers is to advise Dean Kumar based on the diverse expertise we've gained in our respective industries. I see three broad areas where Penn Engineering can have the greatest impact: first and foremost, providing the analytical framework for solving complex problems; second, helping students learn the art of collaboration and working in teams; and third, providing a multidisciplinary education so that graduating engineers have broad horizons to explore.

What do you find most fulfilling in serving as an Overseer?

It's rewarding to work with the dean and his team as they look to evolve the curriculum and focus of the Engineering school. Dean Kumar and his administration are proactive in seeking out our ideas, and are highly responsive. It's fascinating to be involved in these discussions, and exciting to investigate new frontiers in education. 🇺🇸

By Jessica Stein Diamond

Penn Engineering

HONOR ROLL



The faculty, administration, students and staff of Penn Engineering gratefully acknowledge your generosity during our 2018 fiscal year, which ended on June 30. This Honor Roll recognizes those alumni, parents, friends, corporations, foundations and organizations who took part in our ambitious fundraising campaign, The Power of Penn Engineering: Inventing the Future, and supported the next generation of bold, innovative thinkers.

The Honor Roll includes unrestricted gifts to Penn Engineering's Annual Giving Fund, as well as restricted gifts to School-specific priorities. Last fiscal year, donations exceeded \$20.6 million and aligned with the

distinct needs of our renowned faculty, researchers and students. Investments in research programs, new building projects, and endowed faculty chairs bolster our standing as a premier academic institution, while endowed scholarships and fellowships increase access to a Penn education for all qualified and deserving students. Leadership gifts are transformative and remain crucial to our continued growth, pioneering research and teaching.

The Office of Development and Alumni Relations makes every effort to ensure the Honor Roll's accuracy; however, we appreciate your corrections or feedback. Please contact us at alumni@seas.upenn.edu.

Penn Engineering

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ANNUAL GIVING

We are grateful for the generosity of more than 2,100 donors who contributed a record-breaking \$1,359,685 to Penn Engineering Annual Giving in Fiscal Year 2018. The School depends on this unrestricted resource to attract and retain distinguished faculty, fund unique opportunities for students and invest in leading-edge tools and facilities. Here are a few examples:

- We supported the recruitment of 20 new faculty members, bringing our tenure-track faculty count to 131 and our research/practice professor faculty count to 14. Across the board, Penn Engineering faculty members generate new breakthroughs that positively impact our lives and our planet.
- We funded Penn Engineering's Global Biomedical Service Program. This year, students traveled to Shantou, China, to make orthotics for children with neuromusculoskeletal disorders, such as cerebral palsy and multiple sclerosis.
- We renovated laboratories and installed new technology across the School, including 132 new workstations in our computing and instructional labs, new audio-visual equipment in lecture halls, and infrastructure to support teaching in Active Learning Classrooms. The upkeep of our facilities is vital to the success of our research, teaching and recruiting efforts.
- We supported innovative student projects including Ember, an attachment for wood-burning stoves used in refugee camps with the goal of reducing fuel consumption by a third, and ProtoFluidics to create an

adaptable, modular microfluidic device for use in experiments to be conducted by astronauts aboard the International Space Station.

It would not have been possible to undertake these projects and others without the continued commitment and financial support of our annual fund donors. These gifts, which we count on year after year, represent an invisible endowment. To achieve a similar income, an endowment of \$27,193,700 would be required.

In the coming year, we will continue to expand our faculty, improve our facilities and grow our curriculum and student programs. Please use the attached envelope to make your gift to Penn Engineering Annual Giving today. If you have already made your gift for Fiscal Year 2019, thank you for being one of the first to show your support!

INDIVIDUALS

Founded in 1955, the Benjamin Franklin Society (BFS) is the University's unrestricted annual giving leadership group. These distinguished donors make gifts and pledge payments of \$2,500 or more to annual giving funds across the University in a given fiscal year. Through their generosity and vision, members of the BFS exemplify our founder's belief in impactful philanthropy and serve as an inspiration to fellow Penn alumni, parents and friends.

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All Penn Engineering Annual Giving Fund gifts made at the levels above qualify for membership in the BFS.

Red and Blue Society, a University-based giving society, recognizes donors who contribute \$1,000 to \$2,499.

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MODELING TISSUES

Organ-on-a-chip technologies have provided scientists with much more realistic biological models than cells grown on plastic Petri dishes, but their complexity makes it hard to fabricate and deploy them for large-scale testing. Andrei Georgescu (right), a third-year Bioengineering doctoral student in the lab of Professor Dan Huh, has developed precision robotics, analytical software and automated culture platforms that have paved the way for his bench-top models of human tissues to be scaled up for high-throughput drug screening and personalized medicine.

By leveraging these new 3D cell culture techniques alongside tools typically used for microchip patterning at Penn's Singh Center for Nanotechnology, Georgescu has produced microfluidic devices to engineer functional human tissues. His illustration of the ciliated airway model that he is finalizing for launch to the International Space Station is featured on the front cover of this issue.

