



Massachusetts
Institute of
Technology

2018
Year in Review

CONNECTOR

News from the MIT Department of
Electrical Engineering and Computer Science



Year in Review: 2018 Connector



The MIT Stephen A. Schwarzman College of Computing — established with a gift from the co-founder, CEO, and chairman of Blackstone — is scheduled to open in the fall of 2019. Photo: Courtesy of Blackstone.



Rising Stars, an academic-careers workshop for women, brought 76 of the world's top EECS postdocs and grad students to MIT to hear faculty talks, network with each other, and present their research. Photo: Gretchen Ertl

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DONOR RECOGNITION

A LETTER FROM THE DEPARTMENT HEAD

Greetings from MIT!

As I write this, I have just completed my first year as head of the Department of Electrical Engineering and Computer Science — and what a year it has been both for EECS and MIT.

A College for Computing

As this issue goes to press, we are preparing for the new MIT Stephen A. Schwarzman College of Computing. This \$1 billion undertaking represents both the single largest investment in computing and artificial intelligence by a U.S. institution and MIT's most significant structural change in nearly 70 years. Scheduled to open in the fall of 2019, the College will serve MIT's five schools as an interdisciplinary hub for education, research, and innovation in computing and other fields. Plans call for construction of a new building for the College to be completed by 2022. You can learn more about the College, and a related research initiative, the MIT Quest for Intelligence, in the Features section of this issue.

EECS will, of course, be deeply involved in this important new venture. It is expected that the department, along with several other MIT units, will become part of the new College. EECS (in particular the electrical engineering part of the department) will continue to have a strong relationship with the School of Engineering. The College's creation reflects the increasing interest in majors combining computer science with other disciplines; in fact, about 40 percent of MIT undergraduates already major either in computer science or in an academic program combining computer science with another field. EECS has pioneered efforts to meet that demand, most recently launching two new joint academic programs with the Department of Economics and the Department of Urban Science and Planning. For more on the new majors, see the Education News section.

EECS has experienced several other changes and innovations over the past year. Following are some highlights, all covered in this publication's pages:

Leadership Transition

During my inaugural year as department head, I was privileged to work with a stellar leadership team, including several faculty members in new roles: associate department heads Saman Amarasinghe, Joel Voldman, and Nancy Lynch; education officers Elfar Adalsteinsson and Dennis M. Freeman; and undergraduate officer Katrina LaCurts. Please see the Faculty Focus section to learn more about them. I am also grateful for the ongoing collaboration and many contributions of our EECS graduate officer, Professor Leslie Kolodziejcki, and the department's administrative officer, Irene Yong Rong Huang. Irene joined us in December 2017 with more than 12 years' experience at MIT, including the previous three years as the senior financial officer in the Institute of Medical Engineering & Science.



Professor Asu Ozdaglar
Photo: Lillie Paquette/School of Engineering

Faculty Updates, Research Results

EECS faculty members continue to excel. Since the last issue of the *Connector*, six have been appointed to named professorships, nine others have been promoted or received tenure, and more than 50 have received significant awards and honors. We have also added several new members to our faculty. Visit the Faculty Focus section for details on all. EECS faculty also continue to publish the results from their groundbreaking research; for just a few examples, please see the Research Updates section.

Education Improvements

As part of ongoing efforts to improve the undergraduate curriculum, EECS faculty members have launched or overhauled several introductory courses in our majors. In addition, enrollments in our subjects continue to grow. See the Education News section for updates.

SuperUROP Showcase

The Advanced Undergraduate Research Opportunities Program, better known as SuperUROP, remains one of the department's signature programs. The yearlong program provides students with an intensive graduate-level research experience and a seminar covering everything from writing technical papers to presenting results. Last year, thanks to the generosity of an anonymous donor, the program expanded to support students working on projects that combine computer science with the humanities, arts, and social sciences. See the Features section for articles and photos documenting the program's high-energy SuperUROP Showcase poster sessions.

Rising Stars

In October 2018, 76 early-career women in EECS came to MIT for an intensive two-day workshop on academic careers. These top graduate students and postdoctoral researchers, selected from a pool of more than 240 applicants, hailed from 30 universities and organizations from the United States and a few other countries. As the workshop's chair, I was thrilled to see these remarkable women present their research in a poster session, engage with faculty and researchers, and begin to build strong professional networks to support them throughout their careers.

Founded by EECS in 2012, the annual workshop has also been hosted by Carnegie Mellon University, Stanford University, and the University of California at Berkeley. We are pleased to report that of the 309 women who participated in Rising Stars between 2012 and 2017, more than 30 percent held faculty positions as of June 2018. Please see our Rising Stars coverage in the Features section.

Alumni Achievements

As in previous years, a special highlight of this issue is the collection of profiles of EECS alumni who are making a difference in their fields — and in the world. They range from a leading signal-processing expert who teaches, directs a research lab, and runs a nonprofit organization — all while raising five children — to two colleagues whose internet service is making great strides toward bridging the “digital divide” in Myanmar. Read their impressive stories in the Alumni News section.

Signal Processing Symposium

Finally, this issue includes a special report on the Future of Signal Processing Symposium, an international conference held at MIT to mark the 80th birthday of a pioneer in the field, EECS faculty member Alan V. Oppenheim, Ford Professor of Engineering. Although this historic event occurred late in 2017, we felt the event was significant enough to tell you about it here (and the article also includes information about accessing online content and videos).

There is much more to come for EECS in 2019 and beyond, and I look forward to sharing the news about changes and new initiatives in future publications. Meanwhile, we are always happy to hear from EECS alumni, supporters, and friends. Please contact us with your ideas, suggestions, and questions. We welcome your input.

Sincerely,

Asu Ozdaglar

School of Engineering Distinguished Professor of Engineering
Department Head, MIT Electrical Engineering and
Computer Science

“EECS faculty members continue to excel. Since the last issue of the Connector, six have been appointed to named professorships, nine others have been promoted or received tenure, and more than 50 have received significant awards and honors. We have also added several new members to our faculty.”

YOUR TURN

We'd love to hear your feedback on and story ideas for the *Connector*. Which articles did you most enjoy? What suggestions do you have for future features or profiles? Would you prefer to read future *Connectors* in print or online or both? Please send your thoughts to eecs-communications@mit.edu. Thank you!

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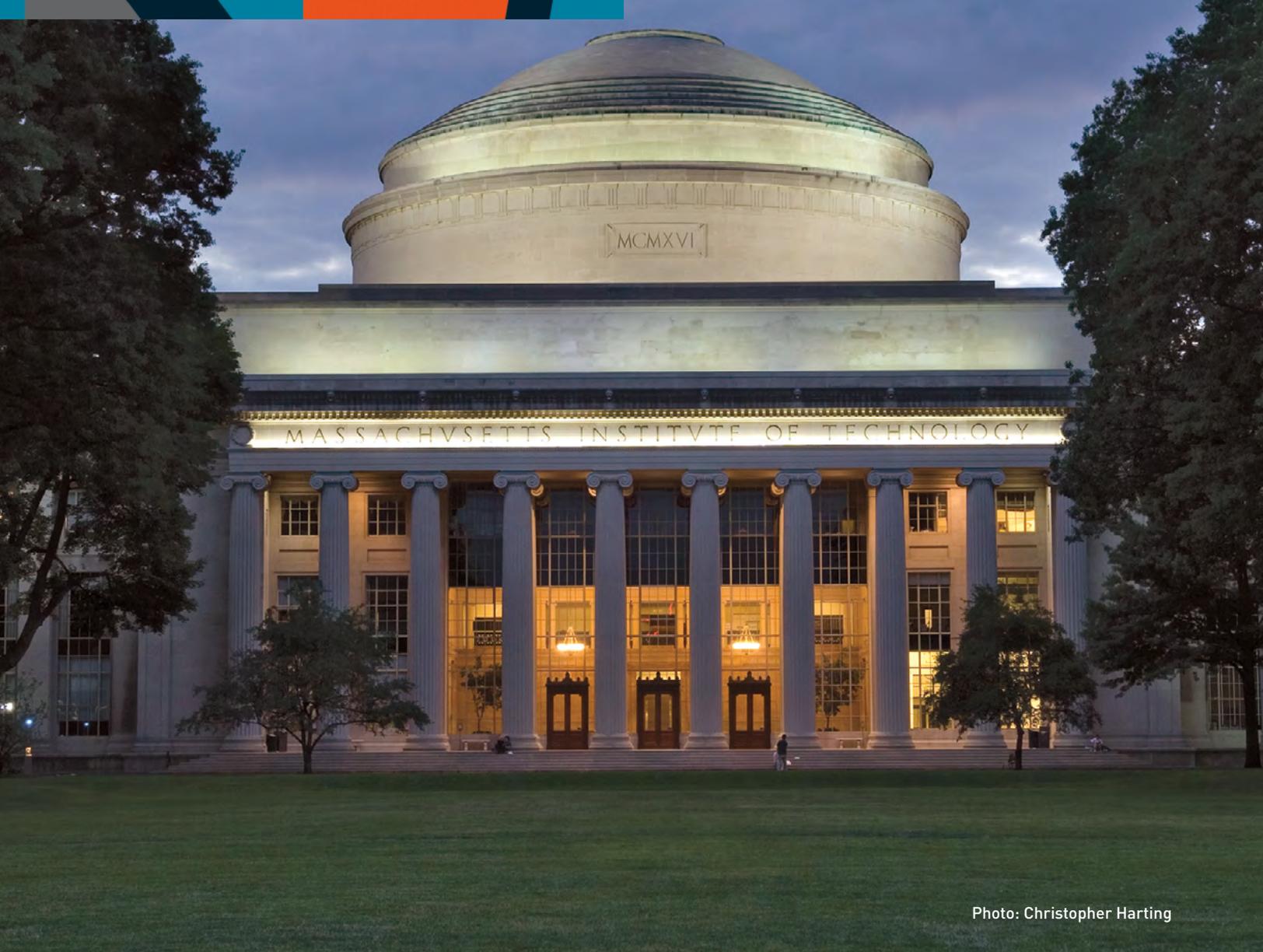


Photo: Christopher Harting

The MIT Stephen A. Schwarzman College of Computing is scheduled to open in the fall of 2019.

MIT RESHAPES ITSELF TO SHAPE THE FUTURE

A gift of \$350 million establishes the MIT Stephen A. Schwarzman College of Computing, key to an unprecedented, \$1 billion commitment to world-changing breakthroughs and their ethical applications.

By MIT News

MIT has embarked on a new \$1 billion commitment to address the global opportunities and challenges presented by the prevalence of computing and the rise of artificial intelligence (AI). The initiative marks the single largest investment in computing and AI by an American academic institution, and will help position the United States to lead the world in preparing for the rapid evolution of computing and AI.

At the heart of this endeavor is the new MIT Stephen A. Schwarzman College of Computing, made possible by a \$350 million foundational gift from the co-founder, CEO, and chairman of Blackstone, a leading global asset manager.

The MIT Schwarzman College of Computing — scheduled to open in the fall of 2019 and move to a signature new building on campus by 2022 — represents the most significant structural change to MIT since the early 1950s. The College will serve MIT's five schools as an interdisciplinary hub for collaborative education, research, and innovation in computing, AI, data science, and related fields. It will also:

- reorient MIT to bring the power of computing and AI to all fields of study, allowing the future of computing and AI to be influenced by insights from all other disciplines;
- create 50 new faculty positions that will be located both within the College and jointly with other departments across MIT, nearly doubling MIT's academic capability in computing and AI;
- educate students in every discipline to responsibly use and develop AI and computing technologies to help make a better world; and
- transform education and research in public policy and ethical considerations relevant to computing and AI.

The Department of Electrical Engineering and Computer Science (EECS) has played a key role in efforts to build bridges and connect their work with other disciplines. In the last two years alone, EECS faculty have established new joint academic programs with economics and urban science and planning.

The creation of the College will accelerate and provide vital support to all kinds of computing-related research and learning already happening across the Institute, says Asu Ozdaglar, School of Engineering Distinguished Professor of Engineering and EECS department head. "With the launch of the College, we hope that MIT's leading position in research and the education of future leaders in computing will continue and grow," she says.

MIT officials expect that EECS, the Computer Science and Artificial Intelligence Laboratory (CSAIL), the Institute for Data, Systems, and Society (IDSS), and the MIT Quest for Intelligence will all become part of the new College; other units may join the College as well. "EECS (and in particular, the electrical engineering part of the department) will naturally continue to have a strong relationship with the School of Engineering, its current home," MIT officials noted in announcing the College's establishment. New faculty committees are being established to define the relationship between EECS, the School of Engineering, and the new College, as well as the range of future degree offerings.

“The MIT Schwarzman College of Computing — scheduled to open in the fall of 2019 and move to a signature new building on campus by 2022 — represents the most significant structural change to MIT since the early 1950s.”

Enhancing MIT's role on the global stage

With the College's founding, MIT seeks to strengthen its position as a key international player in the responsible and ethical evolution of technologies that are poised to fundamentally transform society. Amid a rapidly evolving geopolitical environment that is constantly changing due to technology, the College will have significant impact on the United States' competitiveness and security.

“As computing reshapes our world, MIT intends to help make sure it does so for the good of all,” MIT President L. Rafael Reif said at the time of the announcement in October 2018. “In keeping with the scope of this challenge, we are reshaping MIT. The MIT Schwarzman College of Computing will constitute both a global center for computing research and education,



Stephen A. Schwarzman, Co-founder, CEO, and Chairman, Blackstone
Photo: Courtesy of Blackstone

“There is no more important opportunity or challenge facing our nation than to responsibly harness the power of artificial intelligence so that we remain competitive globally and achieve breakthroughs that will improve our entire society.”

—Stephen A. Schwarzman, Co-founder, CEO, and Chairman of Blackstone

and an intellectual foundry for powerful new AI tools. Just as important, the College will equip students and researchers in any discipline to use computing and AI to advance their disciplines and vice-versa, as well as to think critically about the human impact of their work. With uncommon insight and generosity, Mr. Schwarzman is enabling a bold agenda that will lead to a better world. I am deeply grateful for his commitment to our shared vision.”

Stephen A. Schwarzman is co-founder, CEO, and chairman of Blackstone, which has approximately \$440 billion in assets under management. He is also an active philanthropist with a history of supporting education, culture, and the arts, among other things. In both business and philanthropy, he has focused on tackling global-scale problems with transformative solutions. In 2018, he also gave \$5 million to Harvard Business School to support the development of case studies and other programming that explore the implications of AI on industries and business. In 2013, he founded a highly selective international scholarship program, Schwarzman Scholars, at Tsinghua University in Beijing to educate future global leaders about China. With \$578 million raised to date, the program is modeled on the Rhodes Scholarship and is the single largest philanthropic effort in China’s history coming largely from international donors.

“There is no more important opportunity or challenge facing our nation than to responsibly harness the power of artificial intelligence so that we remain competitive globally and achieve breakthroughs that will improve our entire society,” Schwarzman said. “We face fundamental questions about how to ensure that technological advancements benefit all — especially those most vulnerable to the radical changes AI will inevitably bring to the nature of the workforce. MIT’s initiative will help America solve these challenges and continue to lead on computing and AI throughout the 21st century and beyond.”

At press time, a search for a dean for the new College was well underway, and MIT leaders had met with a variety of stakeholders from across the Institute to answer questions and accept suggestions about the College.

“Our planning benefited greatly from the imagination of many members of our community — and we will seek a great deal more input over the next year,” said Provost Martin A. Schmidt. “By design, the College will not be a silo: It will be connective tissue for the whole Institute.”

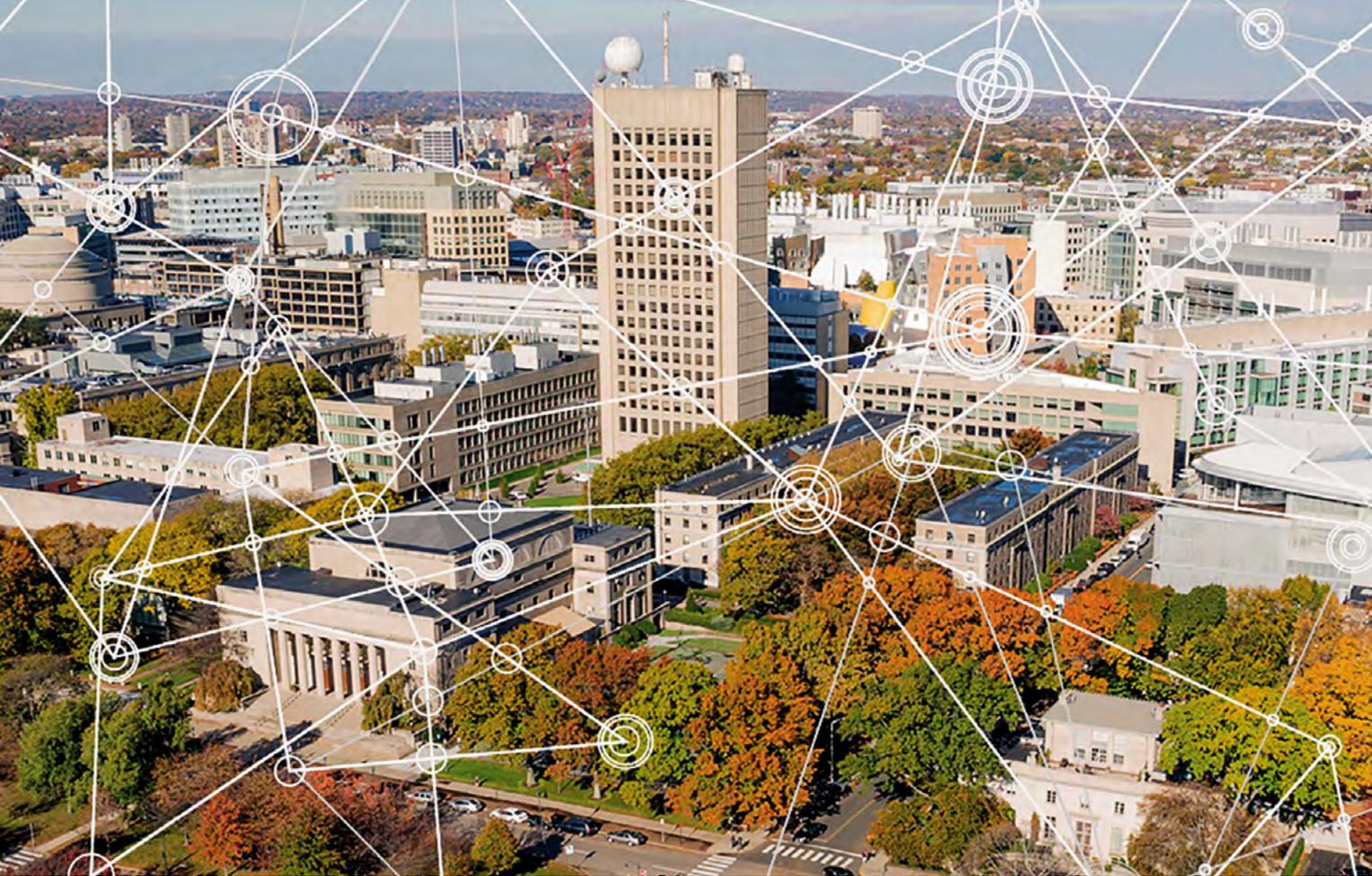
Empowering the pursuit of MIT’s mission

The MIT Schwarzman College of Computing will aspire to excellence in education, research, and innovation. Specifically:

- The College will teach students the foundations of computing broadly and provide integrated curricula designed to satisfy the high level of interest in majors that cross computer science with other disciplines, and in learning how machine learning and data science can be applied to a variety of fields.
- It will seek to enable advances along the full spectrum of research — from fundamental, curiosity-driven inquiry to research on market-ready applications, in a wide range of MIT departments, labs, centers, and initiatives.

The MIT Schwarzman College of Computing will also emphasize policy and ethics to better ensure that the groundbreaking technologies of the future are responsibly implemented for the greater good. To advance these priorities, the College will:

- develop new curricula that will connect computer science and AI with other disciplines;
- host forums to engage national leaders from business, government, academia, and journalism to examine the anticipated outcomes of advances in AI and machine learning, and to influence policies around the ethics of AI;
- encourage scientists, engineers, and social scientists to collaborate on analysis of emerging technology, and on research that will serve industry, policymakers, and the broader research community; and
- offer selective undergraduate research opportunities, graduate fellowships in ethics and AI, a seed-grant program for faculty, and a fellowship program to attract distinguished individuals from other universities, government, industry, and journalism.



The MIT Schwarzman College of Computing will serve MIT's five schools as an interdisciplinary hub for collaborative education, research, and innovation. Graphic: Christopher Harting and Lesley Rock

“Computing is no longer the domain of the experts alone. It’s everywhere, and it needs to be understood and mastered by almost everyone,” Reif said. “In that context, for a host of reasons, society is uneasy about technology — and at MIT, that’s a signal we must take very seriously. Technological advancements must go hand in hand with the development of ethical guidelines that anticipate the risks of such enormously powerful innovations. This is why we must make sure that the leaders we graduate offer the world not only technological wizardry but also human wisdom — the cultural, ethical, and historical consciousness to use technology for the common good.”

Schwarzman also emphasized the importance of the College’s attention to ethics. “We will never realize the full potential of these advancements unless they are guided by a shared understanding of their moral implications for society,” he said. “Advances in computing — and in AI in particular — have increasing power to alter the fabric of society. But left unchecked, these technologies could ultimately hurt more people than they help. We need to do everything we can to ensure all Americans can share in AI’s development. Universities are best positioned for fostering an environment in which everyone can embrace — not fear — the transformations ahead.”

In its pursuit of ethical questions, the College will bring together researchers in a wide range of MIT departments, labs, centers, and initiatives.

The MIT Schwarzman College of Computing will build on MIT’s legacy of excellence in computation and the study of intelligence. In the 1950s, MIT Professor Marvin Minsky and others created the very idea of artificial intelligence. In the years to come, the College’s network function will rely on academic excellence across MIT. Outside of computer science and AI, the Institute hosts a high number of top-ranked departments. *U.S. News and World Report* cites MIT as No. 1 in six graduate engineering specialties — and No. 1 in 17 disciplines and specialties outside of engineering, too, from biological sciences to economics. All are ready to be empowered by advances in these digital fields.

At press time, MIT was preparing to share its vision for the future of computing in a three-day campus-wide celebration scheduled for Feb. 26-28. Highlights were to include activities for MIT students, a day-long symposium for academic leaders, and a capstone forum featuring more than 30 prominent speakers.

For more on the MIT Schwarzman College of Computing, visit news.mit.edu. 📰



ARTIFICIAL INTELLIGENCE IN ACTION

At the MIT-IBM Watson Artificial Intelligence Lab, researchers are training computers to recognize dynamic events.

By Meg Murphy | School of Engineering

Photo: Jake Belcher

MIT President L. Rafael Reif, left, and John Kelly III, IBM senior vice president of Cognitive Solutions and Research, shake hands at the conclusion of a signing ceremony establishing the new MIT-IBM Watson AI Lab.

A person watching videos that show things opening — a door, a book, curtains, a blooming flower, a yawning dog — easily understands that the same type of action is depicted in each clip.

“Computer models fail miserably to identify these things. How do humans do it so effortlessly?” asks Dan Gutfreund, a principal investigator at the MIT-IBM Watson Artificial Intelligence (AI) Laboratory and a staff member at IBM Research. “We process information as it happens in space and time. How can we teach computer models to do that?”

Such are the big questions behind one of the new projects underway at the laboratory, a collaboration for research on the frontiers of artificial intelligence. Launched in the fall of 2017, the lab connects MIT and IBM researchers together to work on AI algorithms, the application of AI to industries, the physics of AI, and ways to use AI to advance shared prosperity. At the time of the launch, MIT announced that the MIT director of the lab would be EECS Professor Antonio Torralba, also a principal investigator in the MIT Computer Science and Artificial Intelligence Laboratory, or CSAIL.

The Moments in Time dataset is one of the projects related to AI algorithms that is funded by the lab. It pairs Gutfreund with Aude Oliva, a principal research scientist in CSAIL, as the project’s principal investigators. Moments in Time is built on a collection of 1 million annotated videos of dynamic events

unfolding within three seconds. Gutfreund and Oliva, who is also the MIT executive director at the MIT-IBM Watson AI Lab, are using these clips to address one of the next big steps for AI: teaching machines to recognize actions.

Learning from dynamic scenes

The goal is to provide deep-learning algorithms with large coverage of an ecosystem of visual and auditory moments that may enable models to learn information that isn’t necessarily taught in a supervised manner and to generalize to novel situations and tasks, say the researchers.

“As we grow up, we look around, we see people and objects moving, we hear sounds that people and objects make. We have a lot of visual and auditory experiences. An AI system needs to learn the same way and be fed with videos and dynamic information,” Oliva says.

For every action category in the dataset, such as cooking, running, or opening, there are more than 2,000 videos. The short clips enable computer models to better learn the diversity of meaning around specific actions and events.

“This dataset can serve as a new challenge to develop AI models that scale to the level of complexity and abstract reasoning that a human processes on a daily basis,” Oliva adds, describing the factors involved. Events can include people,

objects, animals, and nature. They may be symmetrical in time — for example, opening means closing in reverse order. And they can be transient or sustained.

Oliva and Gutfreund, along with additional researchers from MIT and IBM, met weekly for more than a year to tackle technical issues, such as how to choose the action categories for annotations, where to find the videos, and how to put together a wide array so the AI system learns without bias. The team also developed machine-learning models, which were then used to scale the data collection. “We aligned very well because we have the same enthusiasm and the same goal,” says Oliva.

Augmenting human intelligence

One key goal at the lab is the development of AI systems that move beyond specialized tasks to tackle more complex problems and benefit from robust and continuous learning. “We are seeking new algorithms that not only leverage big data when available, but also learn from limited data to augment human intelligence,” says Sophie V. Vandebroek, chief operating officer of IBM Research, about the collaboration.

In addition to pairing the unique technical and scientific strengths of each organization, IBM is also bringing MIT researchers an influx of resources, signaled by its \$240 million investment in AI efforts over the next 10 years, dedicated to the MIT-IBM Watson AI Lab. And the alignment of MIT-IBM interest in AI is proving beneficial, according to Oliva.

“IBM came to MIT with an interest in developing new ideas for an artificial intelligence system based on vision. I proposed a

project where we build data sets to feed the model about the world. It had not been done before at this level. It was a novel undertaking. Now we have reached the milestone of 1 million videos for visual AI training, and people can go to our website, download the dataset and our deep-learning computer models, which have been taught to recognize actions.”

Qualitative results so far have shown models can recognize moments well when the action is well-framed and close up, but they misfire when the category is fine-grained or there is background clutter, among other things. Oliva says that MIT and IBM researchers have submitted an article describing the performance of neural network models trained on the dataset, which itself was deepened by shared viewpoints. “IBM researchers gave us ideas to add action categories to have more richness in areas like health care and sports. They broadened our view. They gave us ideas about how AI can make an impact from the perspective of business and the needs of the world,” she says.

This first version of the Moments in Time dataset is one of the largest human-annotated video datasets capturing visual and audible short events, all of which are tagged with an action or activity label among 339 different classes that include a wide range of common verbs. The researchers intend to produce more datasets with a variety of levels of abstraction to serve as stepping stones toward the development of learning algorithms that can build analogies between things, imagine and synthesize novel events, and interpret scenarios.

In other words, they are just getting started, says Gutfreund. “We expect the Moments in Time dataset to enable models to richly understand actions and dynamics in videos.”



Dan Gutfreund (L), a principal investigator at the MIT-IBM Watson AI Laboratory and a staff member at IBM Research, and Aude Oliva (R), a principal research scientist in CSAIL, are the principal investigators for the Moments in Time dataset, a project funded by the MIT-IBM Watson AI Laboratory. Photo: John Mottern/Feature Photo Service for IBM



EECS PROFESSOR ANTONIO TORRALBA APPOINTED TO DIRECT MIT QUEST FOR INTELLIGENCE

Other EECS faculty and researchers are among those tapped to lead the new initiative in human and machine intelligence.

By MIT News

Photo: Lillie Paquette, School of Engineering

[EECS Professor Antonio Torralba](#)

EECES Professor Antonio Torralba was named as inaugural director of the MIT Quest for Intelligence.

Launched in early 2018, The Quest is a campus-wide initiative to discover the foundations of intelligence and to drive the development of technological tools that can positively influence virtually every aspect of society.

“The range of questions we aspire to explore through The Quest is simply breathtaking,” MIT President L. Rafael Reif said in announcing the initiative. “There are moments in the history of science when the tools, the data, and the big questions are perfectly synchronized to achieve major advances. I believe we are in just such a moment, and that we are poised to advance the understanding of intelligence in every sense in a profound way. Antonio is exactly the leader we need to move this effort forward.”

An expert in computer vision, machine learning, and human visual perception, Torralba is a professor of EECS, the MIT director of the MIT-IBM Watson AI Lab, and a principal

investigator at the Computer Science and Artificial Intelligence Laboratory (CSAIL).

“The Quest is fundamentally a collaboration, so we are excited to watch Antonio build on the success he has already had with the MIT-IBM Watson AI Lab,” Provost Martin Schmidt said in an announcement about the appointment. “Along with the vision and insight he shows in his research, he has remarkable talents as a convener of people and as an enabler of connections.”

Given The Quest’s scale and the breadth of its ambition, Schmidt has also established a robust leadership team to work with Torralba in furthering the initiative’s goals.

Aude Oliva, a principal research scientist at CSAIL and the MIT executive director at the MIT-IBM Watson AI Lab, is The Quest’s executive director.

James DiCarlo, the Peter de Florez Professor of Neuroscience, head of the Department of Brain and Cognitive Sciences, and

principal investigator at the McGovern Institute, is director of “The Core.” One of The Quest’s two linked entities, The Core will advance the science and engineering of both human and machine intelligence. Daniela Rus, the Andrew (1956) and Erna Viterbi Professor of Electrical Engineering and Computer Science, and director of CSAIL, is associate director of The Core.

The Core’s scientific directors are Josh Tenenbaum, professor of computational cognitive science, a research thrust leader at the Center for Brains, Minds and Machines, and a member of CSAIL; and Leslie Kaelbling, the Panasonic Professor of Computer Science and Engineering and a member of CSAIL. The Core’s founding scientific advisor is Tomaso Poggio, the Eugene McDermott Professor of Brain and Cognitive Sciences, director of the Center for Brains, Minds and Machines, a member of CSAIL, and principal investigator at the McGovern Institute. Together, the leadership of The Core will bring together teams of researchers to tackle the most ambitious “moonshot” projects focusing on the science and engineering of intelligence.

Nicholas Roy, professor of aeronautics and astronautics and a member of CSAIL, is the director of The Quest’s second linked entity, “The Bridge.” Dedicated to the application of MIT discoveries in natural and artificial intelligence to all disciplines, The Bridge will host state-of-the-art tools from industry and research labs worldwide. The Bridge’s associate director of strategic initiatives is Cynthia Breazeal, an associate professor of media arts and sciences at the Media Lab. Roy and

Breazeal will work with faculty from across MIT to ensure the discoveries and developments facilitated by The Quest have an impact, both within and beyond academic research.

In all its activities, The Quest is intended to take advantage of — and strengthen — the Institute’s culture of collaboration. The Quest will connect and amplify existing excellence across labs and centers already engaged in intelligence research. It will also establish shared, central spaces conducive to group work, and its resources will directly support research.

“Our quest is meant to power world-changing possibilities,” Anantha Chandrakasan, dean of the MIT School of Engineering and Vannevar Bush Professor of Electrical Engineering and Computer Science, said during The Quest’s kickoff celebration in March. Chandrakasan, in collaboration with Schmidt and all four of MIT’s other school deans, led the development and establishment of The Quest.

“We imagine preventing deaths from cancer by using deep learning for early detection and personalized treatment,” Chandrakasan continued. “We imagine artificial intelligence in sync with, complementing, and assisting our own intelligence. And we imagine every scientist and engineer having access to human-intelligence-inspired algorithms that open new avenues of discovery in their fields. Researchers across our campus want to push the boundaries of what’s possible.”

For more on the MIT Quest for Intelligence, visit <https://quest.mit.edu>. 📷



MIT alumnus Xiao'ou Tang PhD '96, the founder of SenseTime, speaks during a kickoff event for The Quest. SenseTime, a leading artificial intelligence company in China, has partnered with The Quest. Photo: Gretchen Ertl



SUMMIT EXPLORES PIONEERING APPROACHES FOR AI AND DIGITAL TECHNOLOGIES FOR HEALTH CARE

Led by two EECS professors, MIT hosts a conference on new opportunities for collaboration.

By Meg Murphy | School of Engineering

Photo: Lillie Paquette, School of Engineering

Summit speakers included (L to R) Jay Bradner of the Novartis Institute for BioMedical Research; MIT Institute Professor Phillip Sharp; Andrew Plump of Takeda; summit organizers and EECS Professors Regina Barzilay and Dina Katabi; MIT President Emerita Susan Hockfield; and Robert Califf of Duke University.

MIT EECS professors and MacArthur Fellows Regina Barzilay and Dina Katabi gathered leaders in technology, biotech, and regulatory agencies for a summit to inspire widespread adoption of artificial intelligence and digital technologies in health care.

MIT is surrounded by pharmaceutical companies, but until now there has been sparse connection between AI research at MIT and research on drug discovery. The fields have in essence spoken different languages and existed worlds apart.

Barzilay and Katabi are set to change that. In 2017, they started a collaboration with pharmaceutical companies and quickly recognized a wealth of new research questions and an opportunity to transform the process of drug design and manufacturing.

“When Dina and I thought to organize this symposium, we wanted to bring these two communities together, and identify hard questions MIT and pharma can solve together,” said Barzilay, the Delta Electronics Professor in EECS.

She and Katabi, the Andrew and Erna Viterbi Professor in EECS, attracted 120 participants from 15 pharmaceutical companies, the U.S. Food and Drug Administration (FDA), area hospitals, and MIT colleagues in electrical engineering, computer science, biology, and business to the summit.

Bringing digital health to translational medicine

The event kicked off with a welcome from Phillip Sharp, an MIT Institute Professor, professor of biology, and member of the Koch Institute for Integrative Cancer Research, who introduced keynote speaker Jay Bradner, the president of the Novartis Institute for BioMedical Research. Machine learning represents a “new wave to surf on” for the field of biomedicine, said Bradner.

“We so desperately need your help because this science has real challenges,” said Bradner, who leads 6,000 scientists located all over the world. Among them, he said, “150 are data scientists — and that’s not enough.” He ended his keynote with: “I know that together we can totally reimagine medicine.”

Academic researchers presented cutting-edge work and highlighted benefits for clinical trials, which test the safety and efficacy of a new drug. Katabi described a Wi-Fi-like device that uses radio signals to monitor breathing and heart rate. It can also measure gait, detect falls, and monitor sleep and apnea. Katabi emphasized that “the device extracts this information by analyzing the radio waves in the environment. So, there is no overhead to the patient, and no need to wear sensors.” The device is currently deployed with Parkinson’s and Alzheimer’s patients and is used to understand the impact of the disease on mobility, sleep, and dependence on the caregiver.

“Can we leverage complex biological knowledge and vast amount of clinical and genomic data to change the cancer drug discovery process?” asked Dimitris Bertsimas, the Boeing Professor of Operations Research at the MIT Sloan School of Management. He is working on a data-driven approach that involves personalized genomic cancer therapy.

Caroline Uhler, the Henry L. and Grace Doherty Associate Professor in EECS, described the spatial organization of the genome and early cancer detection using neural networks.

“Biomedicine is at an inflection point,” said Andrew Lo, the Charles E. and Susan T. Harris Professor at the MIT Sloan School of Management. As people heed the convergence of the science, engineering, and therapeutics — let’s also consider the economics, he said.

He described using computer algorithms for statistical analysis of the financial returns to biotech and pharmaceutical investments if they invest in a drug’s development. Machine learning models can finely estimate probabilities of success of clinical trials, he said.

“Investors want to know the chance of success,” he said. “You hear talk of Big Pharma getting out of Alzheimer’s because the failure rate in clinical trials have led them to see it as a ‘black hole.’ But if you have more refined analytics that might provide some hope to investors and might attract them to invest.”

AI for better results

Other presentations delved into a wide range of improvements enabled by digital technologies. Barzilay described using machine learning to detect cancer with a complex neural model that can explain the why behind its decisions. “Our model offers interpretability with concise evidence. It takes neural networks and breaks data apart in smart ways to give you an explanation,” she said.

Tommi Jaakkola, the Thomas Siebel Professor in EECS, highlighted the use of machine learning in chemistry. He said it’s time to draw computationally on the millions of known reactions in databases only partially explored — such as articles in chemical, medical, or biological journals and in private repositories. “By digesting the information at scale we can really improve the state of the art,” he said. “The design, the discovery, the optimization. This area is on the verge of exploding.”

This work is being developed as part of the Machine Learning for Pharmaceutical Discovery and Synthesis Consortium that includes leading pharmaceutical companies and an MIT team of computer scientists and chemical engineers.

David Sontag, an assistant professor in EECS, said he wants to see data from claims, clinical trials, disease registries and more used by machine learning for population-level understanding of disease progression.

The adoption of electronic health records in U.S. hospitals has increased nine-fold since 2008 from 9.4 percent to 83.8, he said with approval. But the challenges of machine learning using clinical data are significant, including the amount of missing and heterogeneous data.

Ray Dorsey, the David M. Levy Professor of Neurology at the University of Rochester Medical Center, presented on the “tremendous insights” that Katabi’s technology is delivering for people with Parkinson’s disease.

“We can visualize both their location and frequency and movements and all that can be tracked accurately across long time spans. Until now, our perspective of a patient’s illness experience was episodic and limited,” he said. “Maybe next year, I can come back and say we have highly effective treatments for this disease.”

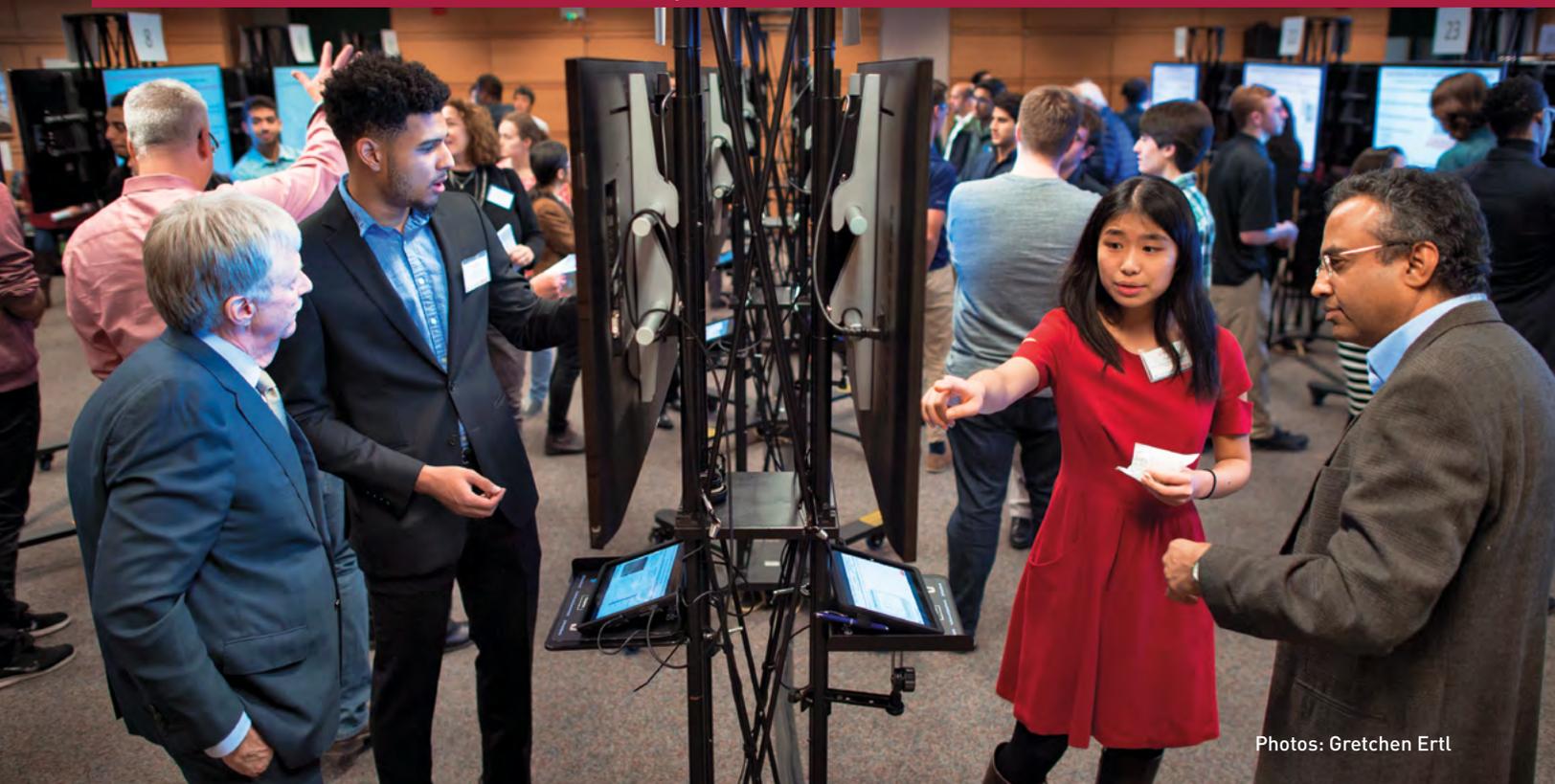
Shaping the future

During another panel, MIT President Emerita Susan Hockfield, a professor of neuroscience in the MIT Department of Brain and Cognitive Sciences, asked: “If we’re lucky, looking forward, how will the FDA onboard digital and machine learning devices?”

“Things have to change, but the fundamental that shouldn’t change is that you have to validate that your technology has human benefit and the benefits outweigh the risk for the intended uses,” said Robert Califf, the vice chancellor for health data science at Duke University and former FDA commissioner.

After the summit, Sharp, a pioneering molecular biologist who earned a Nobel Prize for his co-discovery of RNA splicing, said it had highlighted the promise of AI and digital technologies for improving the lives of patients.

“I expect that working groups will emerge from the meeting that will both formulate collaborative research programs and attract strong financial support,” Sharp said. “It was widely appreciated that the recent remarkable advances in AI and digital technologies will transform biomedical sciences and health care. This vision gave rise to palpable excitement in the audience that will move promise to accomplishment.”



Photos: Gretchen Ertl

About 135 students spoke about their research projects at the well-attended SuperUROP Proposal Pitch poster session.

SUPERUROP: CODING, THINKING, SHARING, BUILDING

MIT juniors and seniors dig deeply into research in yearlong projects.

By Alison F. Takemura | EECS

Sharon Kipruto knew giving birth was a precarious endeavor. In her home country of Kenya, the maternal death rate is many times higher than in the United States — 510 versus 23 deaths per 100,000 live births. In part, that’s because there aren’t enough doctors to meet patient demand. And without visits, women aren’t getting prenatal information that could potentially save their lives.

Kipruto realized this was a problem ripe for intervention. Instead of relying on doctor visits to disseminate information, she thought: “Why not send the information directly to the women?” So she worked on a project that runs with this idea: sending informative, automated text messages. About 88 percent of people in Kenya have mobile phones, so that could be an effective way to give pregnant women information they need, when they need it, says Kipruto, an EECS major.

Kipruto was among 135 students participating in the 2017-2018 Advanced Undergraduate Research Opportunities Program, better known as SuperUROP. Launched by EECS in 2012, the program was later expanded to all departments in the School of Engineering; during the 2017-2018 academic year, for the first time, the program was open to students from the School of Humanities, Arts, and Social Sciences (SHASS) as well.

SuperUROP scholars’ diverse projects include investigations to improve our health, keep us better informed, and make technology more attuned to our feelings.

“It is remarkable in how many fields the students are contributing,” says Dirk Englund, an associate professor of EECS and instructor of 6.UAR, the 12-unit course that all SuperUROP students take.

Many student projects focus on approaches to better treat disease. Claire Goul, a junior in EECS, for example, investigated a tiny biomedical delivery system: DNA nanoparticles. Made of single-stranded DNA, these nanoparticles fold themselves into biological containers, which can transport therapeutic molecules into cells.

Part of maintaining our health is our ability to access and share our detailed medical histories. But right now, the process isn't very streamlined, says Kevin Liu, a senior in mathematics and EECS. "Health care data is not really in the hands of patients. It's in the hands of doctors, hospitals, and health care insurance companies," Liu says. "We want to be able to move this data back to patients, and let patients decide who to share it with."

To do that, Liu worked with blockchain technology, the system that underlies the celebrity digital currency Bitcoin. What makes blockchain so useful is that it keeps track of transactions. When applied to medical records, patients would be able to know who sees their data. An innovative add-on to blockchain code, a feature called "smart contracts," would also allow patients to determine who they want to share data with, as well as who has the ability to update that data. Liu is hoping to build a web interface that makes this technology easy and intuitive to use, even for people who have never coded before.

Information made visible

Other students looked into ways to harness information to benefit society.

Mikayla Murphy, a senior in civil and environmental engineering, used information to hold people accountable. She visualized data collected by the MIT Governance Lab (GOV/LAB)-developed machine learning pipeline, which analyzes city government websites to determine whether those governments are being transparent.

There's reason to look. In 2010, the *Los Angeles Times* published an exposé on the exorbitant salaries of city administrators of Bell, California (population 38,000). Bell's city manager was paid a whopping \$800,000 per year — the nation's highest salary for someone in that role, according to the investigation. Murphy says that practices such as publishing city budgets and meeting minutes online can help citizens keep their representatives, and their payrolls, in check.



SuperUROP guest speaker Katie Rae, CEO and managing partner of The Engine

"I've been really happy working on this project because it's something I've been interested in this entire time here at MIT: how to apply data science skills for social good," Murphy says.

Jeremy Stroming, a senior in aeronautics and astronautics, worked toward a better world — literally. Stroming built a platform for visualizing trends in Earth's subsystems, such as oxygen levels in the oceans, melting sea ice, or changes in average surface temperature.

Stroming's project aims to find ways to better communicate what's happening to the Earth so users can "have a conversation" with the planet. Not only could people better understand the planet and its systems, especially those going awry, but they could also find out about actions they can take using the platform, Stroming says. These might include recommendations for how to adjust diet, support sustainable businesses, or contact government representatives to advocate for change.

Stroming recognizes that learning about the Earth's ills can be intimidating. His goal was making it inviting and empowering. He has been planning a hackathon to make the portal as irresistible as possible, "so that it sucks you in, like Facebook."

Mood music

With its versatility, technology can also improve our leisure. Patrick Egbuchulam, an EECS senior, wanted to enhance video game play by making the music responsive to what a player is experiencing.

Most of the time, video game music is precomposed — fixed, Egbuchulam says. Yet a person could have a totally different experience of the game, with different attendant emotions, from the first time playing to the 10th. Egbuchulam's project was designed to make the soundtrack match player experience in real time. This could include making the music slower and darker for tense, serious moments, or brighter and faster for exciting, hopeful ones, by changing musical traits such as the melody's key, tempo, and mode (major or minor, for example). With this approach, he says, "the music is as unique as a game play."

At a SuperUROP Community Dinner, the students heard guest speaker Katie Rae, CEO and managing partner of The Engine, describe the challenges facing startup founders who are developing tough technologies — that is, breakthrough concepts that require extensive time and funding to bring to market. "Tough-tech companies have historically been underserved and underfunded, leaving many breakthrough inventions stuck in the lab," Rae told the students. The Engine, an MIT-backed organization launched in 2016, provides long-term capital, equipment, lab space, and other support for such companies.

For more information about SuperUROP, including videos and additional photos, visit: superurop.mit.edu. 📷



Photos: Gretchen Ertl

Jacob Higgins, a SuperUROP CS+HASS Scholar, discusses his project during the spring SuperUROP Showcase.

CS+HASS SUPERUROP SCHOLARSHIP PROGRAM DEBUTS WITH NINE PROJECTS

MIT students apply computer science to humanities, arts, and social science research.

By the School of Humanities, Arts, and Social Sciences

Trade policy, government transparency, and music composition systems were among the humanities, arts, and social science (HASS) research areas explored by students in MIT's Advanced Undergraduate Research Opportunities Program, better known as SuperUROP.

These and similar HASS-related research projects materialized because SuperUROP — initially launched by EECS and later expanded to the entire School of Engineering — was extended to support research projects in MIT's School of Humanities, Arts, and Social Sciences. Thanks to a generous grant from an anonymous donor, nine students participated in the yearlong program as the first CS+HASS Undergraduate Research and Innovation Scholars.

"The cool thing about CS+HASS is that a lot of computer science is not yet applied to the social science and humanities fields," says Samir Dutta, who is majoring in computer science with a minor in economics. "You are combining two fields that haven't been combined that much in the past, so it's a great opportunity to find new things. You're pioneering a new type of analysis."

Pioneering students

Dutta's SuperUROP project involved applying machine learning and big data analysis to a dataset of more than 10 billion tariff rate observations with the goal of better understanding the economic and political determinants of tariffs. "His research advances our understanding of the interaction between political institutions and product-level policies," says In Song

Kim, an assistant professor of political science and one of Samir's SuperUROP advisors.

Mikayla Murphy, who is majoring in civil and environmental engineering and minoring in computer science, says that using computer science felt different from anything she had done before. For her SuperUROP project, Murphy worked on MIT GOV/LAB research examining local U.S. government websites and rating them for transparency. Her task was to automate the data analysis system to produce useful fact sheets for government officials and the public.

"Being able to do this cross-disciplinary project applying CS to political science has definitely been very interesting," she says. "I had seen how science labs operate, but in a political science lab it's different. Seeing how my advisor [F. Daniel Hidalgo, the Cecil and Ida Green Associate Professor of Political Science] approaches problems and wants to release all this information to the public — which is not always the goal of scientific research — has been cool."

A deep dive for undergraduates

The SuperUROP program consists of a two-semester course, 6.UAR (Seminar in Undergraduate Advanced Research), and at least 10 hours a week in the lab — making it a deep dive into research that is a new experience for many undergraduates.

"This is my first super-real-serious research endeavor, so it's been a crazy learning experience," says Jacob Higgins, who is majoring in comparative media studies. He did his SuperUROP with Professor D. Fox Harrell, who has appointments in both Comparative Media Studies and the Computer Science and Artificial Intelligence Laboratory. "Being able to interact with people much further along on their journey as researchers is so valuable to me just starting out."

For his project, Higgins worked on a tool for applications such as Chimeria:Grayscale, a video game intended to spark reflection on topics like sexism in the workplace. The tool is designed to automate the work of developers by ensuring interactive narratives take different paths in response to user inputs.



Nitah Nyang'ate Onsongo's SuperUROP CS+HASS project combined computer science and theater arts.

"It's a lot of human-computer interaction," Higgins says, noting that the work called for a truly interdisciplinary skill set. "I did a lot of coding and computational thinking, including applying the fundamentals of software construction I learned in 6.031 to implement the tool. And, from the humanities side, the critical analysis I've done in Comparative Media Studies prepared me to think of stakeholders and evaluate tools using metrics that are correct for this kind of interdisciplinary, human-computer interaction field."

Other CS+HASS SuperUROP research projects were: "Does Democracy Cause Free Trade?" by Emma Bingham; "Eye-Tracking Experiment on Reading Patterns of Non-Natives" by Run Chen; "Spectacles: Assisting Speculative Analysis in Active Archives" by Peter Downs; "Dynamic Background Music for Action Adventure Video Games" by Patrick Egbuchlam; "Theatryc: A New Theater-Arts Communication Platform" by Nitah Nyang'ate Onsongo; and "Real-Time Audio Synchronization" by Smriti Pramanick. 🎧



Smriti Pramanick's SuperUROP CS+HASS project involved real-time audio synchronization for musical concerts.

SUPERUROP + MASTERWORKS: SHOWCASING THE RESULTS OF STUDENTS' REAL-WORLD RESEARCH

SuperUROP and Masterworks participants shared their results during high-energy spring poster sessions.

By Kathryn O'Neill | EECS Contributor

Dozens of MIT undergraduate and graduate students unveiled the results of extensive research projects during the high-energy SuperUROP Showcase + Masterworks poster sessions at MIT's Stata Center.

Addressing topics as diverse as gene expression, smart-home sensing, aircraft propulsion, and theater promotion, about 130 participants in the Advanced Undergraduate Research Opportunities Program — better known as SuperUROP — presented the results of their yearlong projects in two shifts. Immediately following the SuperUROP sessions, nearly 50 EECS master's-degree recipients and candidates shared their own research results.

"It's so satisfying to see the fruition of all this hard work," says Anantha Chandrakasan, dean of the School of Engineering. "The diversity of projects is impressive, as is the level of rigor."

SuperUROP Showcase

Senior Nitah Onsongo, a Course 6-3 (Computer Science and Engineering) major, for example, took advantage of the fact that, thanks to an anonymous donor (see previous story), SuperUROP now supports research involving the School of Humanities, Arts, and Social Sciences (SHASS). Onsongo used machine learning, digital media, and web-development languages to create a tool designed to interest more people in theater. The experience left her an enthusiastic proponent of SuperUROP: "I really encourage everybody to enroll in this program sometime during their years here, because it's helped me to practically apply my skills before going to industry."

Junior Stephanie Ren, also in 6-3, took a more traditional technical SuperUROP route. She developed a system that helps a smart-home sensing device keep track of people inside their houses, and she especially enjoyed the time she spent in the lab. "You're working toward a problem no one has solved yet," Ren says. "Doing that exploration is very different from taking classes."

Chandrakasan launched SuperUROP in EECS in 2012, when he was department head. The program expanded to the full School of Engineering in 2015 and to SHASS in 2017.



Photos: Gretchen Ertl

SuperUROP provides students with an intensive graduate-level research experience supported by a two-term seminar (6.UAR) that covers everything from designing experiments to presenting results. "It's really a compressed version of life in research," says Dirk Englund, an associate professor in EECS and an instructor for the seminar.

The 2017-2018 SuperUROP class includes students from Aeronautics and Astronautics (AeroAstro), Biological Engineering, Civil and Environmental Engineering (CEE), and Chemical Engineering (ChemE), as well as EECS. Many received titles reflecting the industrial sponsors, foundations, and alumni donors whose contributions supported their research.

The 2018 SuperUROP Showcase — which featured 66 big-screen electronic poster boards arrayed all along the Vest Student Street on the Stata Center's first floor — attracted a steady stream of students, faculty, staff, alumni, and industry representatives. Audience members clustered around posters, giving participants a chance to present their work and answer questions in real time.

"It's a great opportunity to develop professional presentation skills," says senior Eric Wadkins (6-3), who described for visitors how he used techniques such as Bayesian inference to help a microscope learn where it is on a sample.

"I think the length of the SuperUROP is such that you can really get something done," says Englund, who supervised Wadkins during the yearlong project and noted that the work has already led to a patent application. In Wadkins' case, Englund says: "He's given a normal microscope a brain to make decisions on its own."

Some who attended the event came because it offers an opportunity to get a sneak peek at the research taking place across the Institute. "It's good to see technology in its earliest and rawest form," says Jake Harrison, a technology scout for Samsung.

Deborah Campbell, associate technology officer for Lincoln Laboratory, praises the "exceptional quality and diversity" of the 2017-2018 SuperUROP projects. "It was clear that the students learned a lot and made significant contributions to the areas they worked in," notes Campbell, whose organization sponsored 12 SuperUROP scholars for 2017-2018. "They communicated this with clear and concise presentations, high-quality posters and demonstrations, and insightful answers to questions."

Ten SuperUROP Scholars received audience-choice awards for their presentations, including Rene Garcia Franceschini of CEE, Erica Ding of ChemE, and Archis Bhandarkar, Nicholas Charchut, Sharlene Chiu, Emily Damato, Kathy Muhlrad, Ryan Prinster, Jason Villanueva, and Larry Wang, all of EECS.

Several SuperUROP scholars, all from EECS, received best-project awards shortly after the closing reception:

- Andrew Ilyas received a 2017-2018 SuperUROP Award for his project "Training GANS with Optimism," supervised by Professor Constantinos Daskalakis.

- Ekin Karasan received the Robert M. Fano Award for her project "An Enhanced Mechanistic Model for Capnography, with Application to CHF-COPD Discrimination," supervised by Professor George Verghese.
- Andrew Rouditchenko received a 2017-2018 SuperUROP Award for his project "The Sound of Pixels," supervised by Professor Josh McDermott.
- Diana Wofk received a 2017-2018 SuperUROP Award for her project "Energy-Efficient Deep Neural Network for Depth Prediction," supervised by Professor Vivienne Sze.

Masterworks

During the Masterworks session, EECS master's students presented the results of thesis research leading to the master of engineering or the master of science degree. Their projects addressed questions in fields ranging from health care to robotics to sustainable energy. As the SuperUROP scholars had, Masterworks participants engaged in lively discussions with attendees about their research approaches and results.

After the session, Englund, who co-directed Masterworks with fellow EECS Associate Professor Vinod Vaikuntanathan, presented three "audience-choice" awards for the best Masterworks posters. Rumen Hristov received first place for "Adding Identity to Device-Free Localization Systems in the Wild." Second place went to Mazdak Abulnaga for "Visualizing the Placenta in a Familiar Way." Third prize was awarded to Tathagata Srimani for "Energy Efficient Computing from Nanotubes to Negative Capacitance." In addition, Rumya Raghavan '17 won the Masterworks Scavenger Hunt for correctly answering the most questions about research discussed on the posters. All four students received prizes provided by Masterworks sponsor Samsung.

Following the ceremony, Abulnaga and Srimani each received a Morris Joseph Levin Award, presented annually by the faculty for the best Masterworks thesis presentations. Professors Polina Golland and Justin Solomon supervised Abulnaga's project, while Professor Max Shulaker supervised Srimani's. 

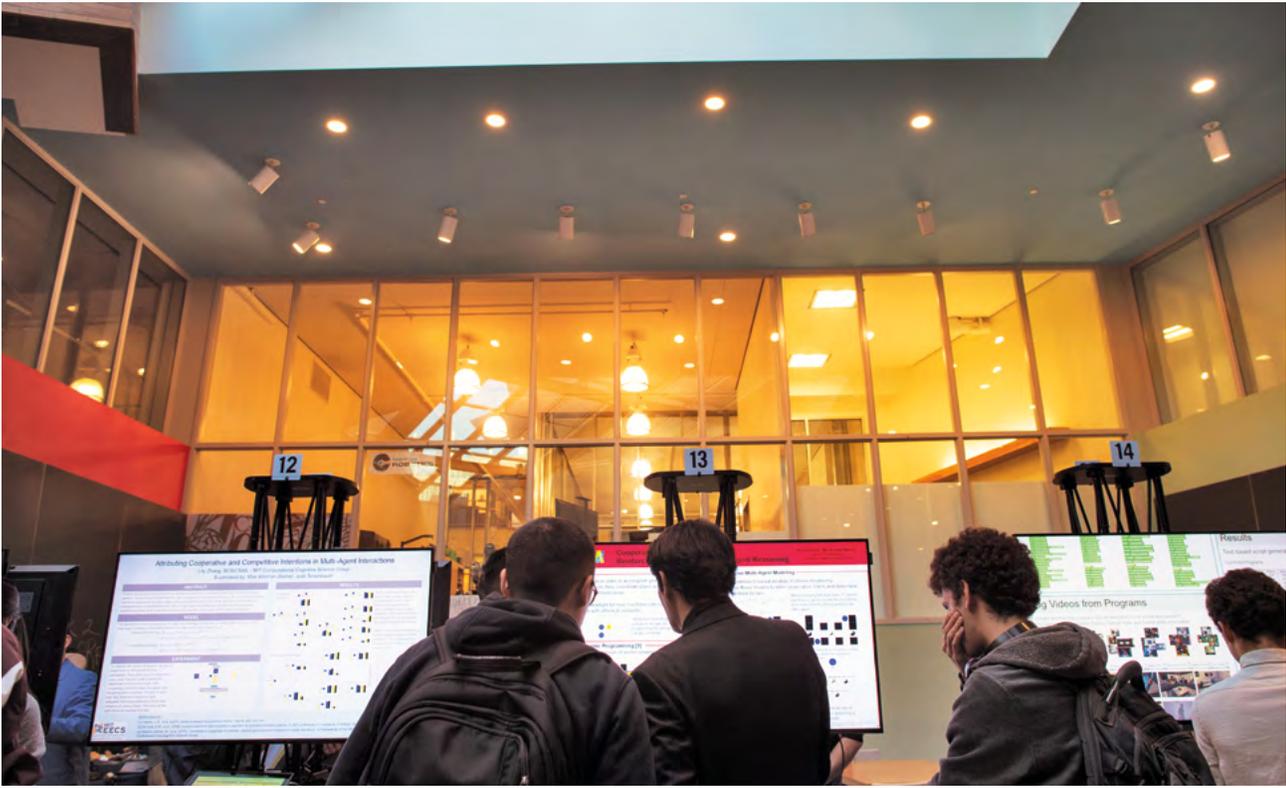


SCENES FROM SUPERUROP SHOWCASE + MASTERWORKS

SuperUROP scholars shared the results of their yearlong research during a high-energy spring poster session on the Charles M. Vest Student Street in the Stata Center. In addition, nearly 50 current and former EECS master's students presented the results of their thesis research.

Photos: Gretchen Ertl







TEAMWORK, TECHNOLOGY, AND TRENDS

At StartMIT's Innovation Night, a veteran entrepreneur shares secrets to success.

By Kathryn O'Neill | EECS Contributor

Photos: Gretchen Ertl

Donna Levin (left), entrepreneur-in-residence at MIT's Martin Trust Center, led a "fireside chat" with StartMIT guest speaker Sue Siegel, GE's chief innovation officer.

When it comes to launching successful entrepreneurial ventures, hot technology is no match for a passionate, driven leadership team, GE Chief Innovation Officer Sue Siegel told about 300 would-be entrepreneurs and guests during StartMIT's Innovation Night at MIT's Samberg Center.

"I have learned over the years that you can take an awesome team with a mediocre technology and it will win over an awesome technology with a mediocre team," said Siegel, who is also CEO of GE Ventures, which partners with startups to accelerate growth and commercialize innovative ideas. "The team that's willing to walk through walls to show that the entity can scale is pretty remarkable."

Siegel was the featured speaker at Innovation Night, an annual highlight of the introductory entrepreneurship class known as StartMIT. During a "fireside chat" with Donna Levin, co-founder of Care.com and entrepreneur-in-residence at the Martin Trust Center for MIT Entrepreneurship, Siegel touched on many of the key challenges entrepreneurs face, from managing teams to keeping abreast of emerging trends.

"Fundamentally, great technology will get you five to seven years" of growth, said Siegel, whose 25-plus years of experience includes leading Affymetrix from a startup to a multibillion-dollar company and working in the venture-capital field. "After that, it's more or less marketing. Your job is to figure out where the new technology horizon is. If you can't do it yourself, partner up."

Siegel said she sees several trends emerging on the horizon, with new ways of working beginning to be adopted across industries. Examples include artificial intelligence (AI) — "Applying AI to any particular industry is the biggest trend" — as well as additive manufacturing and distributed energy.

But she emphasized that building and managing great teams is critical to any endeavor, and she shared five guidelines she gives her own teams as their "rules of engagement:"

1. Team members are ambassadors for the team; what they do reflects on the team.
2. Issues within the team should be resolved within the team.
3. Decisions, once made, need to be supported.
4. Problems should be managed proactively by going directly to the source: "If you've got a bone to pick with me, bring it to me. Don't go to my manager or someone else," Siegel said.
5. Team members should always "assume noble intent."

Siegel underscored this message by asking the audience to consider the entrepreneurs who founded some of today's leading companies, such as Steve Jobs of Apple, Bill Gates of Microsoft, and Larry Page and Sergey Brin of Google. "Think of those entrepreneurs and the teams they built. They're truly special," she said. That's why when GE Ventures considers

what businesses to partner with or invest in, she said: “We focus on team first.”

Making an impact

Gian Carlo Correa, a first-year MBA student who attended Innovation Night, called speakers such as Siegel the best part of participating in StartMIT, a two-and-a-half-week class that draws undergraduates, graduate students, postdocs, and even students from other schools to MIT. Talks and workshops led by a “dream team” of entrepreneurs focus on everything from the ideation process to prototyping and marketing products. “You can learn from experienced speakers,” Correa said. “It’s amazing, their experience: everything from hiring and firing to building an enterprise.”

Founded in EECS in 2014 as Start6 (because EECS is Course 6), StartMIT is an intensive workshop on entrepreneurship held during MIT’s Independent Activity Period (IAP) in January. It has been growing steadily, with 130 students enrolled this year from all five schools at MIT. During this year’s session — among many other activities — students took a one-day tour of startups and established businesses in New York City, honed their creativity during a one-hour crash course in improvisational theater, and engaged in a lively “Ask Me Anything” session with two MIT deans: Anantha Chandrakasan of the School of Engineering and David Schmittlein of the MIT Sloan School of Management.

“StartMIT is all about thinking about impact, how to take ideas and make an impact on the world,” Chandrakasan, who launched Start6 while he was EECS department head, said in introducing the fireside chat. He also noted that in order to encourage collaboration between students and entrepreneurship programs across the campus, StartMIT was for the first time co-sponsored by the School of Engineering and MIT Sloan under the leadership of the Martin Trust Center and the Sandbox Innovation Fund. EECS, as the founding department, continued to provide support for the program.

Learning from failure

Levin began the fireside chat by asking Siegel what drew her to GE Ventures. “The honest to goodness truth is impact,” Siegel said, explaining that while she had had experience in many different environments, from academia to large companies, GE offered her the chance to affect the world through a huge, multinational business with 300,000 employees.

Levin then asked Siegel to share some lessons learned from failure, and Siegel described the experience of recalling a product while heading a fast-growing genomics company. “I learned so much about that in terms of accountability,” she said. “Failure helps you build character.”

On a personal note, Siegel then shared that she still regrets her own decision to return to work just two days after giving birth to her son. “It’s the stupidest mistake I’ve made, to be frank,” she said. “It was a failure of recognition that — regardless of gender — you have the right to be a parent and not let work rob that from you.”

This anecdote struck a chord with audience members. “I love how she shared her personal experiences,” said Ghada Nafie, a mother of three who is starting her second company in collaboration with MIT student colleagues while studying for her PhD in chemical engineering at the University of Calgary in Alberta, Canada. Nafie, who came to Cambridge specifically to attend StartMIT, has found the whole class inspiring. “It’s been amazing,” she said. “It’s really an environment that sets you up for success.”

Startup showcase

The fireside chat was preceded by a showcase of startup companies that have spun out of MIT with the help of a range of MIT resources, from designX, an accelerator run by the School of Architecture and Planning, to delta v, the MIT NYC Summer Startup Studio, and Fuse, all programs run by the Trust Center. Other supporters include the \$100K Competition, the Gordon Engineering Leadership Program, the Legatum Center at MIT, the MIT Environmental Solutions Initiative, the MIT Hong Kong Innovation Node, MIT Ideas, the MIT Media Lab, and the MIT Sustainability Initiative.

Featured startups included Armoire, a clothing rental company; Bitsence, a space planning startup; and Learning Beautiful, an educational toy company.

“I couldn’t say more about how much I love [MIT],” said Kimberly Smith, SM ’17, CEO and co-founder of Learning Beautiful. “It was very fertile ground to begin research,” said Smith, who received a master’s degree in media arts and sciences. She also praised the great number of resources available to startups, including financial prizes, venture mentoring, and legal advice. “More than anything, there’s an attitude that you can go out and do it,” she said. “It’s contagious.”

StartMIT activities continued past the end of IAP, with a group of participants traveling to California over spring break to visit high-tech companies, startups, and venture-capital firms in San Francisco and Silicon Valley. 🚩



The StartMIT Showcase featured startup companies that have spun out of MIT with the help of several Institute resources.



LEARNING ABOUT LEADERSHIP

EECS's workshop for postdoctoral associates reveals the heart of tomorrow's effective research.

By Patricia A. Sampson | EECS Contributor

Photos: Patricia A. Sampson

[Dane deQuillettes](#)

As researchers, postdoctoral associates haven't traditionally expected to become outstanding leaders. Yet many of today's EECS postdocs are increasingly aware of the need to understand and practice effective leadership in the interest of great research.

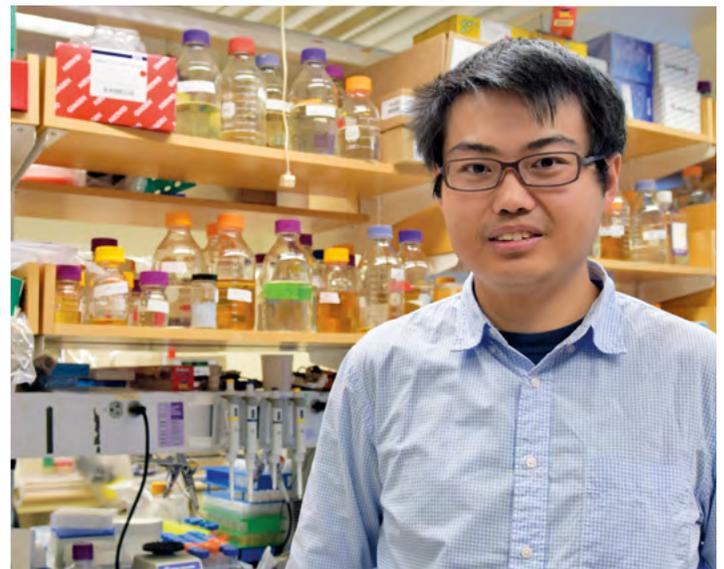
"Leadership is something that interests me a lot," says Philip Krantz, a postdoctoral associate in the Research Laboratory of Electronics (RLE). "Being a postdoc is quite a unique opportunity to develop yourself as a person" — not only in terms of research, but in supervising students and working with principal investigators as well, he says. "In the process, postdocs learn how to become leaders while learning about themselves and about whom they want to be."

As part of a broader effort to create an inclusive environment for EECS postdocs, the department has, under the leadership of Professor Nir Shavit, sponsored workshops on leadership since 2015. Run by a professional consulting firm, the workshops teach participants about conflict resolution,

effective collaboration, and other leadership skills. About 20 postdocs participate in the intensive two-day event each year.

In the fall of 2017, Dane deQuillettes started his postdoc appointment in the Organic and Nanostructured Electronics (ONE) Lab of Vladimir Bulovic, the Fariborz Maseeh (1990) Professor in Emerging Technology and associate dean for innovation in the School of Engineering (who was more recently named founding director of MIT.nano, MIT's new center for nanoscience and nanotechnology, which opened in October 2018). As an undergraduate at Pepperdine University, deQuillettes realized he wanted to devote himself to something that would give back to others. "Science is amazing because there are so many opportunities to have a positive impact on people's lives," he says.

DeQuillettes' motivation to be involved at the cutting edge of solar energy research was also mixed with a strong desire to be part of a vibrant research lab that reflects the kind of leadership he has observed earlier in his life. "I wanted to push myself in terms of leadership roles," says deQuillettes,



Kaie Kubjas

who received a PhD in chemistry and nanotechnology from the University of Washington in 2017. “I had done a lot of stepping into such roles, but know I didn’t always do the best job.”

Within the setting of the postdoc workshop, deQuillettes’ earlier intuitions about leadership were confirmed. “The best leaders don’t act like leaders,” he says. “They lead in the background, trying to understand what motivates each person and how to position them so they feel satisfied in their involvement and accomplishments.” In the end, participants’ goals as both postdocs and leaders are being as productive as possible themselves and helping those around them to be productive and happy as well. “It was nice to see that we had this shared goal,” deQuillettes says. “It wasn’t about wanting to lead and have it my way.”

However, some postdocs aren’t as heavily involved in group dynamics as they work in their research specialties. “I didn’t have a very concrete idea in mind about leadership,” says Cheng Chang, postdoctoral associate with Timothy K. Lu, an associate professor of EECS and Biological Engineering, in the Synthetic Biology Group.

His work to engineer bacteria or other cells in the human gut to treat inflammatory bowel disease (IBD) mostly involves solitary research. So Chang approached the leadership workshop with the realistic goal of building some skills that he can review and apply, even in his everyday life away from the lab. “If my research currently on laboratory mice works,” he notes, “I want to see how it will work for humans.” This might mean creating a startup lab or joining a company — outcomes for which Chang wants to be prepared.

For two years, David Collins, a postdoctoral research fellow under Professor Jungyoon Han in the Micro/Nanofluidic BioMEMS group, has been working on high frequency acoustics with the goal of detecting and separating cells and particles, such as isolating the bacteria that lead to sepsis, a condition that can result in organ shutdown. Collins says he’s excited both about that work and the great diversity of high-powered research being conducted around him in RLE.

Cheng Chang

But he notes that researchers are “siloe d” in their offices. “The most important ways that we can develop relationships with each other is through informal everyday interactions,” he says. His takeaway from the leadership workshop: the importance of voicing the need for such interactions to ultimately encourage a greater exchange of ideas.

Visiting scholar Kaie Kubjas works with Caroline Uhler, the Henry L. and Grace Doherty Associate Professor of EECS in the Institute for Data, Systems, and Society (IDSS). Also in a tenure-track position as an assistant professor in Finland following her current postdoc experience, Kubjas has been focused on developing her leadership skills, including time management and learning how to be more effective in communicating with a wide range of personalities.

Kubjas realized from an earlier assistant professorship in Helsinki that she wasn’t just aiming to become a good researcher in a growing field of mathematics (applied algebraic geometry with applications in the fields of statistics, biology, and optimization). “I saw I had to learn how to efficiently deal with a variety of people,” she says. “My students were all so different. How do I communicate with each of them to keep them motivated?” As a result, she’s recommended the workshop to other postdocs she knows. “It was spot-on with what people like us see at this stage of life.”

Shavit notes that the leadership workshop experience has been so successful that it may be made available to postdocs across the MIT School of Engineering in the future. 



Photo: Justin Knight

RISING STARS IN EECS RETURNS TO MIT

Participants from more than 25 top institutions and companies attended the MIT EECS-sponsored workshop in October 2018.

The workshop brought together 76 early-career women in EECS for an intensive two-day look at life in academia.

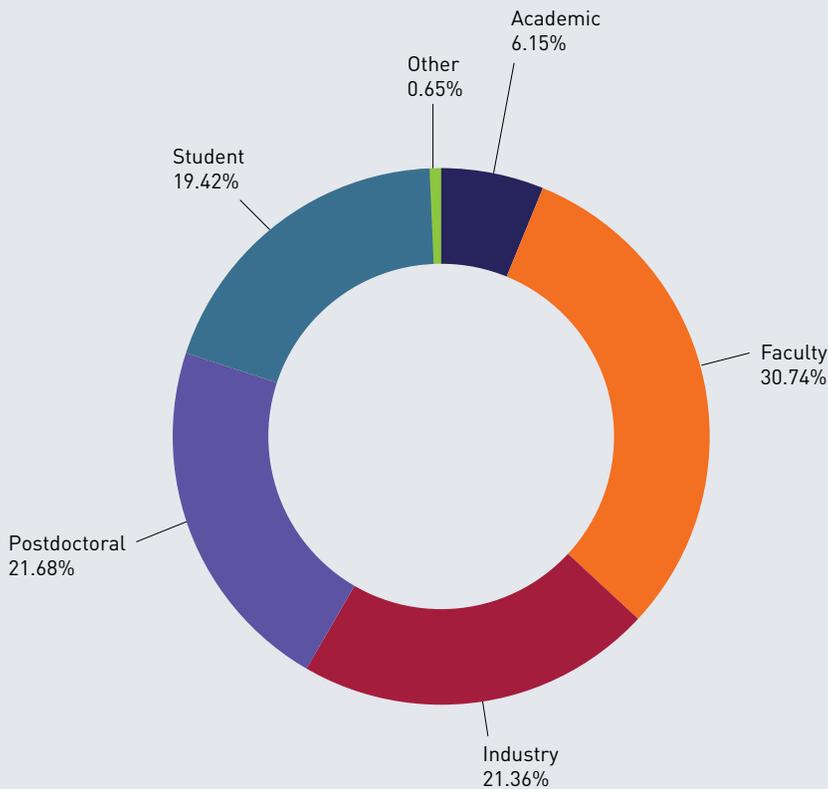
By Anne Stuart | EECS

Some of the world's top EECS graduate students and postdoctoral researchers gathered at MIT in late October 2018 for two days of scientific discussions, informal sessions, and networking. The goal: helping them better understand and navigate the academic hiring and tenure processes.

Topics for the seventh annual workshop included seeking and interviewing for faculty jobs, networking, speaking, teaching, mentoring, obtaining research funding, setting up labs, earning tenure, and maintaining work-life balance.

"Past Rising Stars have been very successful," Asu Ozdaglar, the School of Engineering Distinguished Professor in Engineering and EECS department head, said in welcoming the participants. She noted that more than 30 percent of Rising Stars alumni hold faculty positions and another 20 percent work in industry; most of the rest are still students or postdocs.

EECS launched the Rising Stars workshop in 2012, attracting 33 participants that year and 40 in 2013. In 2014, University of California at Berkeley hosted the workshop (with MIT as a co-sponsor); in 2015, MIT again hosted the event, this time with 61 participants. The event moved to Carnegie Mellon in 2016 and Stanford in 2017.



Past Rising Stars: Where are they now?

Category	# of participants	%
Academic	19	6.15%
Faculty	95	30.74%
Industry	66	21.36%
Postdoctoral	67	21.68%
Student	60	19.42%
Other	2	0.65%
Total Participants (2012-17)	309	100.00%

“We’re very excited that this has gone national,” said Anantha P. Chandrakasan, dean of the School of Engineering and Vannevar Bush Professor of Electrical Engineering and Computer Science. Chandrakasan founded Rising Stars when he was EECS department head, working with Polina Golland, now Henry Ellis Warren (1894) Professor of EECS.

The 2018 Rising Stars in EECS class included graduate students and postdoctoral associates from MIT and more than 20 other U.S. schools, including Carnegie Mellon, Columbia, Georgia Tech, Harvard, Princeton, Stanford, UC Berkeley, and University of Michigan, among others. Also represented were several international institutions, including the Max Planck Institute for Software Systems and the University of Stuttgart in Germany, Tel Aviv University in Israel, and the University of Toronto in Canada.



Welcoming the 2018 Rising Stars in EECS are EECS department head Asu Ozdaglar, the workshop chair, and School of Engineering Dean Anantha Chandrakasan, the workshop advisor. Photo: Gretchen Ertl.

Three current EECS faculty members are past Rising Stars attendees: Tamara Broderick, ITT Career Development Assistant Professor of EECS; Farnaz Niroui, assistant professor of EECS, and Vivienne Sze, associate professor of EECS. A fourth Rising Star alumna, Negar Reiskarimian, a PhD candidate at Columbia, will join the faculty in July 2019.

Niroui and Sze were among the four technical co-chairs of the 2018 Rising Stars workshop, along with Stefanie Mueller, X-Consortium Career Development Assistant Professor of EECS, and Virginia Vassilevska Williams, Steven and Renee Finn Career Development Associate Professor of EECS. Ozdaglar chaired the workshop; Chandrakasan was the workshop’s advisor.

For scenes from Rising Stars in EECS 2018, see the inside back cover of this magazine. To read EECS contributor Kathryn O’Neill’s report on this event, visit the EECS website at eecs.mit.edu. For more about Rising Stars in EECS, including links to websites from past events, visit risingstars18-eecs.mit.edu. 📷

VISITING PROFESSOR ANITA HILL FACILITATES CONVERSATIONS ABOUT THE PAST AND FUTURE OF TITLE IX

By Anne Stuart | EECS

Title IX has been on the books for 46 years — but in Anita Hill’s view, the historic federal law still has plenty to accomplish.

“I don’t think we’ve neglected Title IX in terms of educational access,” says the noted attorney and author, who was a Martin Luther King Jr. Visiting Professor at MIT for the 2017-2018 academic year and remains a research affiliate in the Research Laboratory of Electronics (RLE). “But I do think we have a lot to do in terms of creating an environment where we’re not just saying ‘Women can now enroll in engineering and science,’ but where we’re actively providing ways to overcome the social barriers and implicit biases that keep women from enrolling — or that cause them to drop out.”

While at MIT, Hill led the Gender/Race Imperative, a series of events exploring Title IX, which mandates equal educational opportunities for women, and related issues. Her co-host is Muriel Médard, the Cecil H. Green Professor of Electrical Engineering and Computer Science and head of the Network Coding and Reliable Communications Group in RLE.

Thinking about Title IX

How people view Title IX differs based on generation, notes Hill, who is also University Professor of Social Policy, Law, and Women’s, Gender, and Sexuality Studies at Brandeis University. “People who were in college in the 1970s and ‘80s tend to think of Title IX’s impact on women’s sports,” Hill says, citing the law’s sweeping changes in college athletics during that period.



Visiting Professor Anita F. Hill
Photo: Lillie Paquette, School of Engineering

“Today, young women who think about Title IX think about sexual assault and sexual harassment on campuses.”

However, she continues: “If you look at Title IX, you realize that the mandate is quite broad, and the spirit of Title IX is even broader than the actual mandate.” In fact, Title IX outlaws sexual discrimination in all educational programs and activities that receive federal financial assistance. “This includes admissions, resources, facilities, internships and a whole range of things that happen on the campuses in this country,” Hill says. “It guarantees equal experiences to women and girls in all these areas, as well as in sports, and mandates protections against sexual misconduct.”

No question: things have improved since 1972. But they haven’t improved enough, Hill says. Nearly 50 years after Title IX became law, women in academia still face career disadvantages, often based on unfair presumptions about the choices they’ll make regarding childbirth and child care. “Women starting out in their careers typically don’t have kids, but there’s often an assumption that they’ll be having children, and that can be seen as discounting their value,” Hill says.

Research also suggests that many women who receive PhDs still begin their careers with significantly lower compensation packages than those offered to their male counterparts,

Hill says. “People have always said that’s because women don’t know how to bargain. But it’s not just about bargaining,” Hill says. “Many of these graduates are teaching at academic institutions, so they’re covered by Title IX. The argument I would raise is that women should not have to bargain to have the law enforced.” In other words: the onus should be on the institutions to pay fairly.

As another indicator, she cites a 2012 Yale study in which researchers asked more than 125 scientists to review job applications from identically qualified male and female students. The scientists — women as well as men — consistently rated male candidates more highly than their female counterparts. They were also more likely to hire the men, offer them higher salaries, and provide them with mentoring. Bottom line, Hill says: “There are still disadvantages that are occurring in science even though we’re given access in a technical way.”

Disparities remain at the top as well. “We have created opportunities, but the opportunities for leadership have not improved at the same pace. That’s an issue throughout the academy,” she says. “The number of PhDs women have been getting have been increasing for years. But that hasn’t translated to more women college presidents or more women provosts or more women chairs of departments, or more women in other leadership roles. There are many leadership gaps.”

Those are among the issues explored during the first three sessions Hill moderated at MIT. The opening session featured a panel discussion on the future of Title IX, featuring Catherine Lhamon, chair of the U.S. Civil Rights Commission; Deborah Slaner Larkin, former CEO and current chief advocacy officer at the Women’s Sports Foundation; and Fatima Goss Graves, CEO and president of the National Women’s Law Center.

In a second session, MIT Emeritus Professor Robert M. Gray described life at MIT in the mid-20th century, a time when only about 1 to 3 percent of MIT’s students were women. In a third, a panel of academic leaders discussed academic leaders’ roles in fulfilling Title IX’s promise in science, technology, engineering, and mathematics (the “STEM” fields). Additional events covered related issues during spring term.

Hill emphasizes that her work and studies at MIT extended well beyond traditional concepts of gender, using the same definition now used in many courts. “I’m using the term ‘gender’ in a very broad sense — not just cis female, not just biological female, but also in terms of sexual identity and gender identity. And I add race into the mix, too,” she says. “My point is that you cannot have full opportunity for all women unless you take into account other identity factors. If Title IX is going to help us create opportunity for women and girls, you can’t have that taken away from someone based on their race.”

As the recent #MeToo movement indicates, sexual harassment remains an issue worldwide — and not just on college campuses. That’s an issue that Hill knows all too well. She brought the issue to national prominence in 1991, when she testified before the Senate Judiciary Committee that Supreme Court nominee Clarence Thomas had repeatedly harassed

her when he was her supervisor at the Equal Employment Opportunity Commission. In highly publicized and televised hearings, the all-male committee questioned Hill aggressively; meanwhile, Thomas’ supporters attacked her character and credibility. The Senate narrowly confirmed Thomas’ appointment despite Hill’s testimony, and, as Hill put it in a 1997 memoir, “Speaking Truth to Power,” her life changed forever: “I am no longer an anonymous, private individual — my name having become synonymous with sexual harassment.”

Hill emphasizes that she wasn’t looking to serve as MIT’s diversity officer or Title IX point person. “I’m just coming in as an academic who has been doing policy as well as law and has been trying to get different multidisciplinary views and input into what works and what doesn’t,” she says. “This is just to get different groups of people talking about the same topic and educating us all. My role is not only to present, but to take what we learn from this and try to put it into a framework that can be used in other locations.”

In any case, there’s no danger that the conversations will end anytime soon, she says: “There’s enough to discuss here that we could talk about this for a year and still not duplicate anything.”

“No question: things have improved since 1972. But they haven’t improved enough, says Visiting Professor Anita Hill. Nearly 50 years after Title IX became law, women in academia still face career disadvantages, often based on unfair presumptions about the choices they’ll make regarding childbirth and child care.”



Special Report

ENVISIONING THE FUTURE OF SIGNAL PROCESSING

Intellectual descendants and colleagues of MIT professor Alan V. Oppenheim gathered to mark his 80th birthday and discuss the future of a quietly prolific scientific field.

By Alison F. Takemura | EECS

Photo: Gretchen Ertl

Alan V. Oppenheim, Ford Professor of Engineering, introduces a panel during the lively Future of Signal Processing Symposium.

We live in a sea of signals. “They’re natural, manmade, medical; speech, music; synthetic; physical signals, and communication,” says Meir Feder, professor of electrical engineering and Information Theory Chair at Tel Aviv University.

For example, when we snap a photo with our phones, record a funny cat video, or tell Siri to write a text, technology is taking signals from the environment — for instance, analog audio and visual information — and making it digital: into ones and zeros that machines can read. The information comes out the other end, where it appears reanimated, or processed, into something we can use and understand.

There’s a whole field devoted to studying how to listen and watch for such signals, and then transform and translate them. Most of us have just never heard of it — which might be a testament to its impact. “I think that one indicator of the power of signal processing is that it doesn’t get credit anymore,” says Anantha Chandrakasan, Vannevar Bush Professor of Electrical Engineering and Computer Science (EECS), and dean of the MIT School of Engineering. “It’s everywhere.”

The comments came as a group of researchers marked the 80th birthday of one of the pioneers in the field of digital signal processing (DSP): Alan V. Oppenheim, MIT’s Ford Professor of Engineering. With Ron Schafer, professor emeritus at Georgia Tech, Oppenheim coauthored the textbook *Discrete-Time Signal Processing*. “Some edition of this book is — or should be —

on every DSP engineer’s shelf,” says Tom Baran, research affiliate in MIT’s Research Laboratory of Electronics’ DSP Group, co-founder and CEO of Lumii, and the lead organizer of both a dinner in Oppenheim’s honor and the Future of Signal Processing Symposium.

During the day-long symposium, researchers defined the next wave of problems that this field will tackle. These included applications in security, forensics, and health. The researchers also described some unexpected areas of science that will help propel the field: quantum physics, 19th-century algebra, and a signal’s customary nemesis: noise.

A signal in the darkness

Signal processing can make us safer, Chandrakasan says. His research group is developing processing techniques to enhance the security of devices that comprise the so-called Internet of Things (IoT). “Everything that can be connected to the internet wirelessly can be hacked,” says Chandrakasan, a member of the symposium’s organizing committee.

Data in the right hands, of course, can be a security boon. Symposium speaker Admiral John Richardson, 31st Chief of Naval Operations for the U.S. Navy, explains that physical shipbuilding can’t keep up with the Navy’s actual demand. Instead of only more ships, there’s a need to make better ships, he says. Using advanced signal processing, a fully networked fleet

would be able to listen in the water and respond with greater coordination, giving them a tactical advantage.

“Signal processing has a terrific and important role in making our Navy more capable,” Richardson says.

New approaches in signal processing could also support combating terrorism and locating criminals. Another symposium speaker, Min Wu, professor of electrical and computer engineering at the University of Maryland, illustrates the point with a video recording of Osama bin Laden. “Many people fighting terrorism want to know when the video was shot, where the video was shot,” she says.

To help answer that question, Wu and her team have developed signal processing techniques to use tiny variations in the electric grid that result from the miniscule changes in its electric frequency that happen all the time. For a recording inside a room, for example, that might translate to an ever-so-slight flickering of the lights. Outside, it could be the subtle changes in ambient sounds of power equipment connected to the grid.

The variations allow researchers to localize the signal to whichever electric grid has the same fingerprint. Right now, it’s possible to differentiate recordings done in places with completely separate electric grids — for instance, distinguishing between recordings made in the western United States from those done in India or Lebanon. Even that level could help narrow down the locations of terrorist cells, Wu says. The U.S. Department of Homeland Security has also approached her to help determine where victims of child pornography were filmed.

Richard Baraniuk, professor of electrical and computer engineering at Rice University and founder and director

of OpenStax, spoke at the symposium about how signal processing can help crack open the black box of why machine learning is so effective.

Another speaker, Martin Vetterli — president of École Polytechnique Fédérale de Lausanne — dazzled the audience by talking about his group’s recent effort in high-quality digital acquisition and rendering of rare artifacts. He showed how to revive the Lippmann photography method by making the process digital in order to create astonishingly vivid images. He also presented a process of virtual relighting applied to one of the oldest well-preserved New Testament manuscripts, called Papyrus 66. Despite being projected on a screen, the papyrus looked as real as if it were right in front of the audience.

Body signals

Signal processing can help manage internal threats as well as those from the outside. Chandrakasan and his group have developed a low-power cap of electrodes to detect changes in brain-wave patterns that herald an oncoming seizure. By alerting patients eight to 10 seconds in advance, the technology allows them to move into a safer position or environment.

Another application is in the treatment of cancer. Symposium speaker Ron Weiss — an MIT professor in both the departments of Biological Engineering and EECS and the director of MIT’s Synthetic Biology Center — and his group have developed proof-of-concept biological circuits. These process biochemical signals into a desirable outcome: targeting and destroying cancer cells.

How this currently works is that an engineered virus is injected into the bloodstream of a mouse. From there, it makes its way into a cell. Then it does a computation: does it sense the right combination of four to six biomarkers that indicate the cell is



Symposium speaker Admiral John Richardson, 31st Chief of Naval Operations for the U.S. Navy



Participants in a Future of Signal Processing Symposium panel respond to audience questions. (L to R): Professor Alexander Rakhlin of the University of Pennsylvania, Professor Asu Ozdaglar of MIT, and Professor Yonina Eldar of Technion-Israel Institute of Technology.

cancerous? If the answer is “yes,” the virus flips into “destroy” mode. This kind of biological circuit is itself a signal processing system.

Processing updates

As new applications emerge in signal processing, novel approaches are brewing as well.

Drawing on work pioneered by Oppenheim and his then-student Yonina Eldar (now professor of electrical engineering at Technion-Israel Institute of Technology and a member of the symposium’s organizing committee), Isaac Chuang believes quantum physics will play a role in signal processing.

“Signals from the physical world are actually quantum as they come in,” says Chuang, another symposium speaker who is professor of EECS and physics and senior associate dean of digital learning at MIT. “The faintest light from the moon is a quantum signal.” Quantum computing — replacing the ones and zeroes of traditional computers with quantum states — could make calculations for processing signals faster.

Math from the 19th century could also provide a boost to signal processing, says Feder, of Tel Aviv University. Take the quaternion: an extension of complex numbers, but with four elements instead of two. It’s useful for representing certain signals that correspond to the location and orientation of a three-dimensional body in space, like a rotation, he says.

Quaternions may not be the only promising mathematics that could be useful in future signal processing. They’re a special case of a broader branch called Clifford algebras, says Petros Boufounos, senior principal research scientist at Mitsubishi Electric Research Laboratories, adding that all Clifford algebras deserve a second look. “They provide you with

amazing structure,” says Boufounos, another member of the symposium’s organizing committee.

Finally, noise and randomness, the historical foes of signals, may prove beneficial. “Intentional randomness is something we don’t completely understand,” Boufounos says. But it can improve performance, he adds. Boufounos shows a picture of a videographer on MIT’s campus with its buildings in the background. When filtered to remove pixels with less contrast, the background disappears. But adding noise brings those features, previously lost, back.

“Randomness can be very useful if we properly harness it,” Boufounos says.

The horizon of innovations in signal processing seems endless. There is no want in demand, according to Oppenheim. “There will always be signals,” he’s often said. “And they will always need processing.”

The Future of Signal Processing Symposium opened with remarks from MIT Provost Martin A. Schmidt and concluded with a panel discussion, “The Venn Diagram Between Data Science, Machine Learning, and Signal Processing,” moderated by Oppenheim. Panelists included Eldar and Schafer, along with Professor Asu Ozdaglar, now head of MIT’s EECS Department; Professor Alexander Rakhlin of the University of Pennsylvania; and Professor Victor Zue, Delta Electronics Professor of EECS at MIT.

Baran was the event’s lead organizer; organizing committee members included Boufounos, Chandrakasan, and Eldar.

For more on the symposium — including event photos and videos of presentations — please visit futureofsp.eecs.mit.edu. 

SCENES FROM COMMENCEMENT 2018

On June 8, 2018, MIT awarded degrees to 999 undergraduates and 1,821 graduate students.

Photos: Gretchen Ertl

Commencement speaker Sheryl Sandberg, chief operating officer of Facebook, urged graduates to remember that “the most difficult problems and the greatest opportunities are not technical, they are human.” At the colorful 2018 Investiture of Doctoral Hoods, professor and journalist Candis Callison SM '02, PhD '10, urged MIT’s doctoral graduates to “make the world a more just, more fair place.”

In all, EECS awarded 107 doctoral degrees, 130 master of engineering (MEng) degrees, 87 master of science (SM) degrees, and 400 bachelor degrees during the 2017-2018 academic year.

Here’s a sampling of photos from EECS celebrations following the 2018 hooding and commencement ceremonies. 📷





Photo: Dominick Reuter



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CHASING COMPLEXITY

EECS faculty member Ryan Williams has taken a key step toward solving the biggest problem in theoretical computer science.

By Larry Hardesty | MIT News

In his junior year of high school, Ryan Williams transferred from the public school near his hometown of Somerville, Alabama — “essentially a courthouse and a couple gas stations,” as he describes it — to the Alabama School of Math and Science in Mobile.

Although he had been writing computer programs since age 7 — often without the benefit of a computer to run them on — Williams had never taken a computer science class. Now that he was finally enrolled in one, he found it boring, and he was not shy about saying so in class.

Eventually, his frustrated teacher pulled a heavy white book off a shelf, dumped it dramatically on Williams’s desk, and told him to look up the problem described in the final chapter. “If you can solve that,” he said, “then you can complain.”

The book was “Introduction to Algorithms,” co-written by MIT computer scientists Charles Leiserson and Ron Rivest and one of their students, and the problem at the back was the question of P vs. NP, which is frequently described as the most important outstanding problem in theoretical computer science.

Twenty-two years later, having joined the MIT Department of Electrical Engineering and Computer Science (Course 6, EECS) faculty with tenure this year, Williams is now a colleague of both Leiserson and Rivest, in the Theory of Computing Group at MIT’s Computer Science and Artificial Intelligence Laboratory. And while he hasn’t solved the problem of P vs. NP — nobody has — he’s made one of the most important recent contributions toward its solution.

P vs. NP is a problem in the field of computational complexity. P is a set of relatively easy problems, and NP is a set of problems some of which appear to be diabolically hard. If $P = NP$, then the apparently hard problems are actually easy. Few people think that’s the case, but no one’s been able to prove it isn’t.

As a postdoc at IBM’s Almaden Research Center, Williams proved a result about a larger set of problems, known as NEXP, showing that they can’t be solved efficiently by a class of computational circuits called ACC. That may sound obscure, but when he published his result, in 2010, the complexity theorist Scott Aaronson — then at MIT, now at the University of Texas — wrote on his blog, “The result is one of the most spectacular of the decade.”



EECS Associate Professor Ryan Williams. Photo: Bryce Vickmark

“We all knew the goal was to walk on the moon (i.e., prove $P \neq NP$ and related separations),” Aaronson later added, “and what Ryan has done is to build a model rocket that gets a couple hundred feet into the air, whereas all the previous rockets had suffered from long-identified technical limitations that had kept them from getting up more than 50 feet. ... It’s entirely plausible that those improvements really are a nontrivial step on the way to the moon.”

Basic principles

Williams is the son of a mother who taught grade school and a father who ran his own construction firm and whose family indoctrinated Williams into one side of a deep Alabamian social divide — the side that roots for Auburn in the annual Auburn-Alabama football game.

Most of his father’s construction contracts were to dig swimming pools, and when Williams was in high school and college, he was frequently his father’s only assistant. His father ran the backhoe, and Williams followed behind the bucket, digging out rocks and roots, smoothing the ground, and measuring the grade with a laser level.

His father was such a backhoe virtuoso that, Williams says, “If I was going too slow, he would take the edge of the bucket and start flattening the ground and raking it himself. He would say, ‘Point the level here and see if it’s grade.’”

In first grade, having scored highly on a standardized test the year before, Williams began taking a class one day a week at a school for gifted children on the opposite side of the county. He was entranced by the school’s Apple II computer and learned to program in BASIC. The next year, the class had a different teacher and the computer was gone, but Williams kept writing BASIC programs nonetheless.

For three straight years, from eighth through 10th grade, he and a partner won a statewide programming competition, writing in the oft-derided BASIC language. They competed as an undersized team, even though the state technology fair sponsored an individual competition as well. “It just didn’t seem fun to spend two or three hours straight programming by myself,” Williams says.

After his junior-year introduction to the P vs. NP problem, Williams was determined to study theoretical computer science

in college. He ended up at Cornell University, studying with Juris Hartmanis, a pioneer in complexity theory and a winner of the Turing Award, the Nobel Prize of computer science. Williams also introduced his Yankee classmates to the ardor of Alabamian football fandom, commandeering communal televisions for the annual Auburn-Alabama games.

“It was pretty clear to the other people who wanted to watch television that, no, I needed it more, and that maybe I was willing to fistfight,” Williams says.

After graduating, he did a one-year master’s degree at Cornell and contributed a single-authored paper to a major conference in theoretical computer science. Then he headed to Carnegie Mellon University and graduate study with another Turing-Award-winning complexity theorist, Manuel Blum.

Leaps and bounds

Blum told Williams that he was interested in two topics: k -anonymity — a measure of data privacy — and consciousness. k -anonymity seemed slightly more tractable, so Williams dove into it. Within weeks, he had proven that calculating optimal k -anonymity — the minimum number of redactions necessary to protect the privacy of someone’s personal data — was an NP-complete problem, meaning that it was (unless someone proves P equal to NP) prohibitively time consuming to compute.

Such proofs depend on the calculation of lower bounds — the minimum number of computational steps necessary to solve particular problems. As a potential thesis project, Williams began considering lower bounds on NP-complete problems when solved by computers with extremely limited memory. The hope was that establishing lower bounds in such artificially constrained cases would point the way toward establishing them in the more general case.

“I had studied these things for years, and at some point it occurred to me that these things have a pattern,” Williams says. His dissertation ended up being an automated technique for proving lower bounds in the context of memory-constrained computing. “I wrote a computer program whose output — when certified by a human — is proving that there are no efficient programs for this other problem,” he says.

After graduating, Williams did one-year postdocs at both CMU and the Institute for Advanced Study, in Princeton, New Jersey. Then came his research fellowship at IBM and his “spectacular” result.

That result came from an attempt to bridge a divide within theoretical computer science, between researchers who work on computational complexity and those who design algorithms. Computational-complexity research is seen as more abstract, because it seeks to make general claims about every possible algorithm that might be brought to bear on a particular problem: None can do better than some lower bound. Algorithm design seems more concrete, since it aims at simply beating the running time of the best algorithm developed so far.

But in fact, Williams argues, the problems are more symmetric than they first appear, because establishing an algorithm’s minimum running time requires generalizing about every possible instance of a particular problem that it will ever have to face. Williams wondered whether he could exploit this symmetry, adapting techniques from algorithm design to establish lower bounds.

“Reasoning about lower bounds just seems really hard, but yet, when it comes to designing algorithms to solve the problem, it’s somehow just more natural for people to think about,” Williams says. “People are just naturally problem solvers. Maybe if you phrased the problem the right way, it would become an algorithmic problem.”

Computational jiu-jitsu

Any NP-complete problem can be represented as a logic circuit — a combination of the elementary computing elements that underlie all real-world computing. Solving the problem is equivalent to finding a set of inputs to the circuit that will yield a given output.

Suppose that, for a particular class of circuits, a clever programmer can devise a method for finding inputs that’s slightly more efficient than solving a generic NP-complete problem. Then, Williams showed, it’s possible to construct a mathematical function that those circuits cannot implement efficiently.

It’s a bit of computational jiu-jitsu: By finding a better algorithm, the computer scientist proves that a circuit isn’t powerful enough to perform another computational task. And that establishes a lower bound on that circuit’s performance.

First, Williams proved the theoretical connection between algorithms and lower bounds, which was dramatic enough, but then he proved that it applied to a very particular class of circuits.

“This is essentially the circuit class where progress on P not equal to NP stopped in the mid-’80s,” Williams explains. “We were gradually building up some steam with slightly better, slightly better lower bounds, but it completely stopped in its tracks because of this one pesky little class that nobody could get a handle on.”

Since Williams’s breakthrough paper, both he and other complexity theorists have used his technique for translating between algorithms and lower bounds to prove results about other classes of problems. But, he explains, that translation cuts both ways: Sometimes, a failed attempt at establishing a lower bound can be translated into a more efficient algorithm for solving some other problem. Williams estimates that he has published as many papers in the field of algorithm design as he has in the field of computational complexity.

“I’m lucky,” he says. “I can even publish my failures.” 🍷

GENOME PACKING AND NETWORK MODELS



Professor Caroline Uhler

By Caroline Uhler | Henry L. and Grace Doherty Associate Professor in EECS and the Institute for Data, Systems, and Society (IDSS), Member of the Laboratory for Information and Decision Systems (LIDS), and Member of MIT's Machine Learning Group, Operations Research Center, and Statistics + Data Science Center.

Background

In each cell in our bodies, our genetic information is contained in an approximately 3-meter-long polymer chain (the DNA), which is tightly packed into a container (the cell nucleus). While the genetic information in each cell is the same, our body consists of hundreds of different cell types that have different shapes and functions, such as blood cells, skin cells, muscle cells, and neurons. It is a fundamental biological question to understand how it is possible to build all these different cell types from the same one-dimensional (1D) string of information.

At the heart of this question is the need for understanding how genes interact to produce gene-expression patterns that code for a particular cell type. In recent years, there has been increasing evidence that the 3D organization of the DNA in the cell nucleus plays a crucial role. For example, certain regions in the genome can be more densely packed than others and, therefore, less accessible, or genes that are spatially close can co-regulate each other more easily. The emerging hypothesis is that a different spatial arrangement of the DNA can lead to different gene regulatory networks and thus gene expression patterns[6]. In fact, various diseases such as different cancers, premature aging (progeria syndrome), and various neurodegenerative diseases have been associated with defects in the packing of the DNA[7]. For that reason, a major challenge is to understand the rules that govern DNA-packing and, in particular, the mapping between the 3D organization of the genome and its expression.

The rise of genome-editing techniques such as the CRISPR-Cas system hold promise for new avenues for preventing and treating human diseases. These technologies give scientists the ability to change an organism's DNA by adding, removing, or altering the 1D genome sequence at a particular location. The human genome consists of approximately 20,000 genes that interact in different ways in each cell type. Genome-editing techniques allow interventions on any of the 20,000 genes (i.e., nodes of the network) and also combinations thereof. For the first time in history, it is now possible to obtain large interventional datasets. Such data represent new statistical challenges: How can interventional data be used to learn about the underlying regulatory network? How can we predict the effect of a yet-unseen intervention? Which interventions should be performed to obtain the most information about the

underlying network? How do interventions in the 1D sequence interact with the 3D organization of the genome? And, ultimately, which interventions should be performed to revert a diseased cell back to its normal state?

Causal inference and gene regulation

Answering questions about interventions and their effects on the global system are at the heart of causality. It is well known that, in general, correlation does not imply causation. However, patterns of correlation or, more generally, statistical dependence, can imply causation, even if the data is purely observational. This fact was formalized by Jerzy Neyman in the 1920s. Independently, Sewall Wright pioneered the use of networks to represent cause-effect relationships in complex multivariate settings. His structural equation models (SEMs) made it possible, via careful analysis and appropriate assumptions, to draw causal conclusions from observational data — that is, without resorting to a randomized controlled trial. However, the larger statistics community generally did not pick up these ideas, and skepticism among statisticians resulted in the causal interpretation of SEMs being downplayed and eventually forgotten. The reemergence of causal inference from observational data began in the 1970s with major contributions by Judea Pearl in computer science, Donald Rubin in statistics, Peter Spirtes in philosophy, Jamie Robins in epidemiology, and Kevin Hoover in economics[3]. Since the overwhelming majority of available data has been observational, research to date has mostly focused on the development of algorithms and the assumptions needed to infer causality from observational data[4,5].

From observational data alone, a causal network is generally not completely identifiable. For example, one cannot distinguish whether A causes B or B causes A. In both cases, A is correlated with B and, therefore, we can only infer that there is a connection between the two variables, but not the direction of the arrow. Distinguishing the two cases would require an intervention. Interventions come in two forms[2]. A hard intervention eliminates the dependency between the targeted variable and its direct causes. An example is a (perfectly performed) gene-knockout experiment, where the expression of a gene is set to zero. A soft intervention, on the other hand, only modifies the causal relations between targeted variables and their direct causes without eliminating them. Examples are gene-knockdown experiments. It is natural to expect that hard interventions provide more information about the underlying causal network than soft interventions do. Surprisingly, we showed in recent work that despite being more invasive, hard interventions do not improve the identifiability of causal links over soft interventions[10]. In addition, we provided the first provably consistent algorithms for identifying the causal network from a mix of observational and interventional

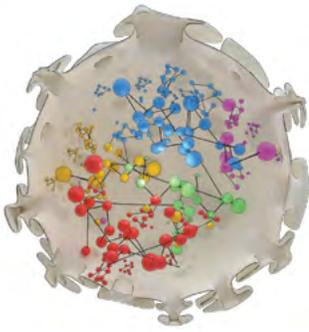


Figure 1: Artistic illustration of chromosome organization within the cell nucleus as revealed by network analysis. Chromosomes (individually depicted in different colors) are spatially arranged to optimize gene expression with chromosome intermingling regions containing regulatory hotspots of co-regulated genes and transcription machinery. Courtesy of Diego Pitta de Araujo, MBInfo.



Figure 2: Schematic depicting cell types positioned within islands and potential reprogramming paths between these cell types. Cells can transition either within or between islands by crossing local or global epigenetic barriers by altering gene expression directly or indirectly through the 3D organization of the genetic material [adapted from [6]].

data[9,10]. Current research efforts are concentrated on extending these results to interventions with off-target effects and the development of a theory of optimal experimental design for the selection of interventions.

Genome packing and gene regulation

Studying the biochemical networks inside a cell and perturbations thereof using genome editing techniques only represents one side of the coin. In recent years, experiments have demonstrated that the gene-expression pattern can also be changed by deforming a cell and thereby altering the packing of the DNA inside the cell nucleus. In recent work, we introduced a model for the organization of chromosomes that links the morphology of the cell nucleus with gene expression. In this model, the spatial arrangement of chromosomes is viewed as a configuration of ellipsoids (the chromosomes) packed into an ellipsoidal-shaped container (the cell nucleus). The shape of the container is defined by mechanical constraints on the cell, and cell type-specific configurations are determined by solving an optimization problem, where the pairwise overlap between chromosome pairs is penalized on the basis of their difference in gene expression levels. We validated this model in collaboration with G.V. Shivashankar's experimental biology laboratory by fluorescently labeling specific chromosomes in cells that were micropatterned into different shapes[8].

To obtain more fine-grained insights into the 3D organization of the DNA, scientists have developed chromosome conformation capture methods. These techniques use a chemical treatment to fix the 3D structure of the DNA, followed by cutting the DNA at defined locations, sequencing the fragments that are glued together, and mapping them back to a reference genome. This procedure provides the contact frequencies of the DNA at the whole genome level. The difficulty in using such data is that it is obtained as an average over a large heterogeneous population of cells. In recent work, we provided a network modeling approach to infer inter-chromosomal gene clusters from such data by overlaying it with 1D functional data, such as gene expression. Interestingly, we found that the identified

chromosome intermingling regions are often transcription hotspots, with an accumulation of co-regulated genes and transcription machinery[1]. To visualize the chromosome organization in the cell nucleus, think of a chromosome as a subway line. Regions where multiple lines connect and intersect are typically important or busy areas of a city, such as business districts, transportation hubs, or major shopping zones. Similarly, regions of the nucleus where different chromosomes intermingle are likely to be important for gene expression.

Summary

The 3D organization of the DNA is tightly linked to gene expression and regulation. Deciphering the cell-type specific 3D maps of chromosome organization and the spatial transcription hotspots is of major interest. Scientists are starting to use the packing signature for early detection of various diseases[7]. In addition, deciphering the mechanogenomic code that links chromosome organization with gene expression could ultimately allow us to understand cellular reprogramming, namely how alterations in chromosomal contact maps can change transcriptional programs to output a different cell type[6]. Computational models such as the ones presented here, which combine the mathematical theory of packing with the statistical theory of causal networks, are able to link the spatial organization of chromosomes with cell shape and gene expression and can thereby provide important insights into processes such as differentiation, trans-differentiation, and reprogramming. 

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CLOSING THE LOOP ON REDUCING PATIENT-MONITORING ALARMS IN NEONATAL CRITICAL CARE



Professor Thomas Heldt

By Thomas Heldt | W.M. Keck Career Development Professor in Biomedical Engineering; Associate Professor of Electrical and Biomedical Engineering; Core Faculty Member, Institute for Medical Engineering and Science (IMES), and Principal Investigator, Research Laboratory of Electronics (RLE)

Patients in hospital intensive care units (ICUs) generally have life-threatening conditions and tend to be physiologically unstable. Providing life support to these patients entails close monitoring of their physiologic state and rapid therapeutic intervention. These tasks are facilitated through an impressive array of bedside medical devices that acquire and report continuous measurements of vital organ function, and serve to monitor and control the delivery of therapy. Examples of common measurements and device-assisted interventions in the neonatal intensive care unit (NICU), for example, include multi-channel electrocardiography, pulse oximetry, possibly an invasive blood pressure measurement, mechanical ventilation, and automated infusion of medications.

Apart from displaying the measured signals for visual inspection, essentially all bedside devices analyze the acquired signals and issue visual and audible alarms, either to indicate changes in the patient's physiologic state (patient alarms) or to alert the medical staff to technical problems with the measurements (technical or device alerts). Such bedside alarm notifications can be life-saving when they alert care providers to a life-threatening condition that requires immediate attention and decisive action. Fortunately, such acute decompensation tends to be rare. Unfortunately, however, the expansion of bedside monitoring technology has resulted in a proliferation of the alarm burden. Detailed alarm audits in modern ICUs reported over 30 distinct audible alarm signals and hundreds of issued alarms per patient-day[1]. This burden is exacerbated by the fact that most bedside monitoring alarms are either technically false or clinically irrelevant, a situation very reminiscent of the proverbial child who cried "wolf"[2].

High alarm rates do more than impose a significant burden on health care providers. They also put patient lives at risk as providers respond to the high rate and low specificity of monitoring alarms with desensitization ("alarm fatigue") — that is, they ignore the vast majority of alarms, which can result in patient deaths as truly life-threatening conditions may go unnoticed. This possibility presents a clear and tangible threat to patient safety that urgently needs to be addressed[3].

In the context of neonatal critical care, very limited data have been available in the medical literature on the types of

alarms that drive the overall NICU alarm burden. Additionally, the physiological state of the preterm neonate changes significantly throughout the first few postnatal months, which suggests that the types and rates of monitoring alarms depend on the infant's developmental state.

To help address the problem of alarm fatigue in neonatal critical care, we established a close collaboration with Wendy Timpson, M.D., and Munish Gupta, M.D., of the Department of Neonatology at Boston's Beth Israel Deaconess Medical Center (BIDMC). Our goals in this line of research were two-fold. First, we set out to comprehensively characterize the alarm burden by type of alarm and by developmental state of the infant to understand the "epidemiology" of the NICU bedside monitoring alarms. Second, we sought to leverage this characterization into actionable and impactful changes in care policy at BIDMC to safely reduce the alarm burden over time.

Characterizing the alarm burden

We collaboratively addressed our first goal as part of a SuperUROP project of former EECS student Taibo Li '15, MEng '17, by mining more than 2 million bedside monitoring alarms from the medical center's NICU. (Editor's note: For more on the Advanced Undergraduate Research Opportunities Program, better known as SuperUROP, please see the features section of this magazine.) Our work was enabled by a decade-long collaboration between MIT, BIDMC, and Philips Healthcare. Under the leadership of Roger Mark, Distinguished Professor of Health Sciences and Technology and of EECS (and an IMES faculty colleague), the collaboration established the Multiparameter Intelligent Monitoring in Intensive Care II (MIMIC-II) project to archive and disseminate multimodal bedside monitoring data streams and associated clinical information[4]. From the MIMIC-II database, we were able to extract and analyze the physiological trend data and associated alarm notifications from a convenience sample of more than 900 NICU patients[5].

Our results show that the alarm burden at the medical center's NICU is very substantial, with an average alarm rate of more than 180 alarms per patient-day, or — on average — one alarm issued every eight minutes per patient. In the 48-bed NICU, such an alarm burden makes for a near-continuous cacophony of monitoring alarms. We also established that the alarm rate strongly depends on an infant's developmental status, with alarm rates exceeding 400 to 500 alarms per patient-day in extreme preterm infants.

Regarding the alarm types, we confirmed prior reports that the majority of all NICU alarms were due to simple threshold-crossing events of heart rate (HR) and blood oxygen saturation (SpO2). In these alarm-limit violations, an alarm gets issued every time an infant's second-by-second HR or SpO2 measurement exceeds the corresponding High alarm limit or drops below the corresponding Low alarm threshold.

To further characterize these threshold-crossing episodes, Minoru Matsushima, a visiting scientist in MIT's Medical Electronic Device Realization Center (MEDRC), and EECS graduate student Jonathan Birjiniuk '15, MEng '17 detected each of these events in the associated HR and SpO2 trends. They determined, for each episode, the maximum absolute deviation (or excursion) from the prevailing threshold and the duration over which the alarm-limit violation persisted. Figure 1 shows the empirical distribution functions for excursion and duration for the HR high alarm-limit violations. The vast majority of all HR High alarm episodes are of comparatively short duration and limited excursion.

Turning insights into changes in care practice

Based on the results from our analysis, Timpson and Gupta initiated a quality-improvement process at the NICU to increase the HR High alarm limit from 200 to 210 beats per minute. To ensure that no infant was put at undue risk because of this change in care practice, the NICU team had to file daily reports documenting any adverse events that may be a consequence of the more liberal alarm settings. The change in care practice went into effect in early March 2018 and has resulted in a reduction of the HR High alarm burden by about a factor of two (see Figure 2). Most important: from early March through early July, no adverse event was attributed to the change in care practice, and the NICU team was allowed to discontinue daily filing of adverse-event reports. Ultimately, the change in alarm settings was considered safe for the patients and welcomed by the nursing staff.

Going forward

While the HR High threshold-crossing alarms form a sizeable fraction of all monitoring alarms in the NICU, more than 40 percent of all patient alarms relate to the SpO2 signal. At BIDMC, these episodes account for more than 75,000 patient alarms per month. Our next task is to understand patterns of oxygenation in the preterm neonate and to understand which SpO2 alarm-limit violations are inconsequential and which violations put the infants at risk for significant injury, such as retinopathy of prematurity, hypoxic-ischemic brain injury, and necrotizing enterocolitis. In tackling this challenge, we are benefitting from a recent upgrade in the BIDMC data-archiving system put in place under the MIT-Philips collaboration. The patient-monitoring data from all 48 NICU beds are now streamed to MIT in quasi-real time. The data is available for analysis within 24 hours from signal acquisition, providing an incredible opportunity for rapid-cycle acquisition, analysis, and feedback to the BIDMC clinical team to close the loop on identifying opportunities for alarm reduction and translation into clinical practice. 🇺🇸

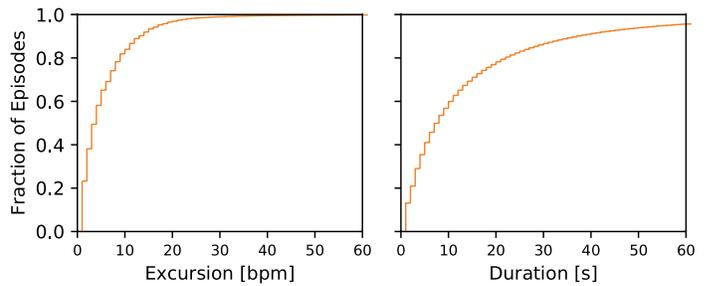


Figure 1: Empirical distribution of maximum deviation ("excursion") from alarm threshold and duration of 242,214 episodes exceeding the Heart Rate (HR) High alarm limit.

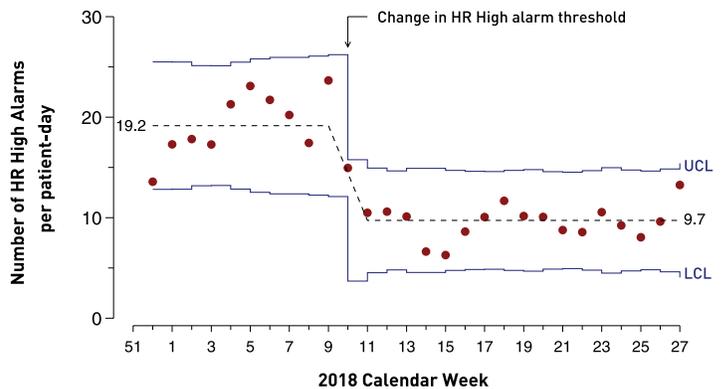


Figure 2: Control chart representation of the effects of the Heart Rate High alarm threshold increase from 200 beats/min to 210 beats/min on Heart Rate High alarm burden at the Beth Israel Deaconess Medical Center NICU. The change in alarm threshold led to a reduction in Heart Rate High alarms by about 12,000 alarms/month without putting patient safety at risk. UCL: Upper control limit; LCL: Lower control limit.

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NOVEL TRANSMITTER PROTECTS WIRELESS DATA FROM HACKERS

Device uses ultrafast “frequency hopping” and data encryption to protect signals from being intercepted and jammed.

By Rob Matheson | MIT News Office

Today, more than 8 billion devices are connected around the world, forming an “Internet of Things” (IoT) that includes medical devices, wearables, vehicles, and smart household and city technologies. By 2020, experts estimate that number will rise to more than 20 billion devices, all uploading and sharing data online.

But those devices are vulnerable to hacker attacks that locate, intercept, and overwrite the data, jamming signals and generally wreaking havoc. One method to protect the data is called “frequency hopping,” which sends each data packet, containing thousands of individual bits, on a random, unique radio frequency (RF) channel, so hackers can’t pin down any given packet. Hopping large packets, however, is just slow enough that hackers can still pull off an attack.

Now MIT researchers have developed a novel transmitter that frequency hops each individual 1 or 0 bit of a data packet, every microsecond, which is fast enough to thwart even the quickest hackers.

“Because the channel selection is quick and random, and there is no fixed frequency offset, a hacker can never tell which bit is going to which channel.”

The transmitter leverages frequency-agile devices called bulk acoustic wave (BAW) resonators and rapidly switches between a wide range of RF channels, sending information for a data bit with each hop. In addition, the researchers incorporated a channel generator that, each microsecond, selects the random channel to send each bit. On top of that, the researchers developed a wireless protocol — different from the protocol used today — to support the ultrafast frequency hopping.

“With the current existing [transmitter] architecture, you wouldn’t be able to hop data bits at that speed with low power,” says Rabia Tugce Yazicigil, a former postdoc in EECS and first author on a paper describing the transmitter, recently presented at the IEEE Radio Frequency Integrated Circuits Symposium.

“By developing this protocol and radio frequency architecture together, we offer physical-layer security for connectivity of everything.” Initially, this could mean securing smart meters that read home utilities, control heating, or monitor the grid. “More seriously, perhaps, the transmitter could help secure medical devices, such as insulin pumps and pacemakers, that could be attacked if a hacker wants to harm someone,” says Yazicigil, now an associate professor of electrical and computer engineering at Boston University.

Co-authors on the paper are Anantha P. Chandrakasan, dean of MIT’s School of Engineering and the Vannevar Bush Professor of Electrical Engineering and Computer Science (EECS); visiting research student Kapil Vaidya; former MIT postdoc and EECS alumnus Phillip Nadeau ’10, SM ’11, PhD ’16; and EECS alumni Daniel Richman ’17 and Chiraag Juvekar SM ’14, PhD ’18.

Ultrafast frequency hopping

One particularly sneaky attack on wireless devices is called selective jamming, where a hacker intercepts and corrupts data packets transmitting from a single device but leaves all other nearby devices unscathed. Such targeted attacks are difficult to identify, and difficult to combat with current packet-level frequency-hopping transmitters.

With frequency hopping, a transmitter sends data on various channels, based on a predetermined sequence shared with the receiver. Packet-level frequency hopping sends one data packet at a time, on a single 1-megahertz channel, across a range of 80 channels. A packet takes around 612 microseconds for Bluetooth low-energy (BLE)-type transmitters to send on that channel. But attackers can locate the channel during the first 1 microsecond and then jam the packet.

“Because the packet stays in the channel for a long time, and the attacker only needs a microsecond to identify the frequency, the attacker has enough time to overwrite the data in the remainder of packet,” Yazicigil says.

To build their ultrafast frequency-hopping method, the researchers first replaced a crystal oscillator — which vibrates to create an electrical signal — with an oscillator based on a BAW resonator. However, the BAW resonators only cover about 4 to 5 MHz of frequency channels, falling far short of the 80-MHz range available in the 2.4-gigahertz band designated for

wireless communication. Continuing recent work on BAW resonators — in a 2017 paper co-authored by Chandrakasan, Nadeau, and Yazicigil — the researchers incorporated components that divide an input frequency into multiple frequencies. An additional mixer component combines the divided frequencies with the BAW’s radio frequencies to create a host of new radio frequencies that can span about 80 channels.

Randomizing everything

The next step was randomizing how the data is sent. In traditional modulation schemes, when a transmitter sends data on a channel, that channel will display an offset — a slight deviation in frequency. With BLE modulations, that offset is always a fixed 250 kilohertz for a 1 bit and a fixed -250 kHz for a 0 bit. A receiver simply notes the channel’s 250-kHz or -250-kHz offset as each bit is sent and decodes the corresponding bits.

But that means, if hackers can pinpoint the carrier frequency, they too have access to that information. If hackers can see a 250-kHz offset on, say, channel 14, they’ll know that’s an incoming 1 and begin messing with the rest of the data packet.

To combat that, the researchers employed a system that each microsecond generates a pair of separate channels across the 80-channel spectrum. Based on a preshared secret key with the transmitter, the receiver does some calculations to designate one channel to carry a 1 bit and the other to carry a 0 bit. But the channel carrying the desired bit will always display more energy. The receiver then compares the energy in those two channels, notes which one has a higher energy, and decodes for the bit sent on that channel.

For example, by using the preshared key, the receiver will calculate that 1 will be sent on channel 14 and a 0 will be sent on channel 31 for one hop. But the transmitter only wants

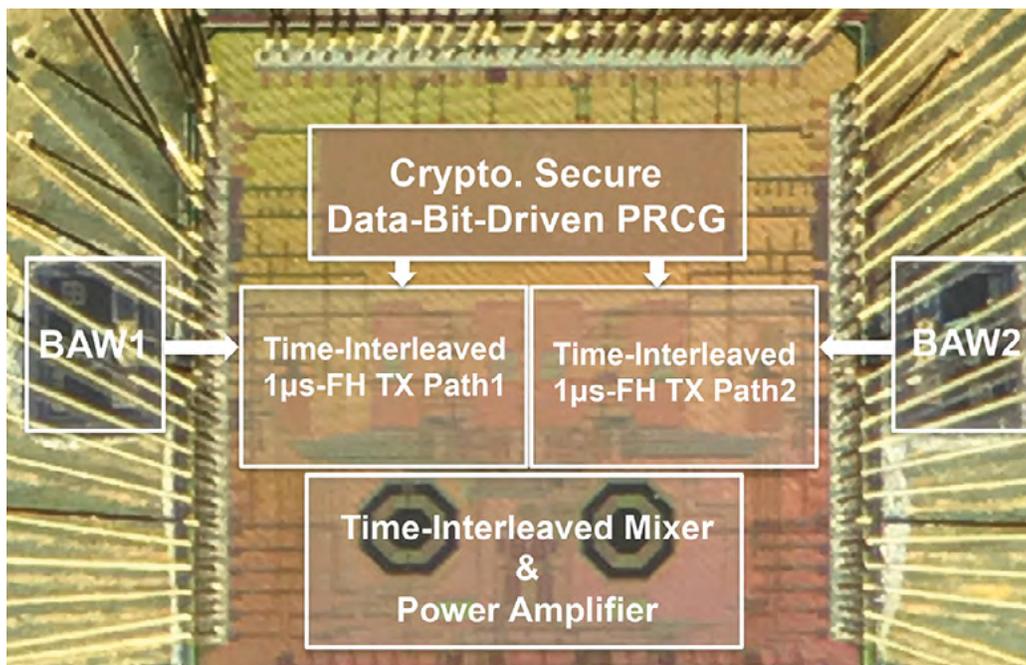
the receiver to decode a 1. The transmitter will send a 1 on channel 14, and send nothing on channel 31. The receiver sees channel 14 has a higher energy and, knowing that’s a 1-bit channel, decodes a 1. In the next microsecond, the transmitter selects two more random channels for the next bit and repeats the process.

Because the channel selection is quick and random, and there is no fixed frequency offset, a hacker can never tell which bit is going to which channel. “For an attacker, that means they can’t do any better than random guessing, making selective jamming infeasible,” Yazicigil says.

As a final innovation, the researchers integrated two transmitter paths into a time-interleaved architecture. This allows the inactive transmitter to receive the selected next channel, while the active transmitter sends data on the current channel. Then, the workload alternates. Doing so ensures a 1-microsecond frequency-hop rate and, in turn, preserves the 1-megabyte-per-second data rate similar to BLE-type transmitters.

“Most of the current vulnerability [to signal jamming] stems from the fact that transmitters hop slowly and dwell on a channel for several consecutive bits. Bit-level frequency hopping makes it very hard to detect and selectively jam the wireless link,” says Peter Kinget, a professor of electrical engineering and chair of the department at Columbia University. “This innovation was only possible by working across the various layers in the communication stack requiring new circuits, architectures, and protocols. It has the potential to address key security challenges in IoT devices across industries.”

The work was supported by Hong Kong Innovation and Technology Fund, the National Science Foundation, and Texas Instruments. The chip fabrication was supported by TSMC University Shuttle Program. 



MIT researchers developed a transmitter that frequency hops data bits ultrafast to prevent signal jamming on wireless devices. The transmitter’s design (pictured) features bulk acoustic wave resonators (side boxes) that rapidly switch between radio frequency channels, sending data bits with each hop. A channel generator (top box) each microsecond selects the random channels to send bits. Two transmitters work in alternating paths (center boxes), so one receives channel selection, while the other sends data, to ensure ultrafast speeds. Image: Courtesy of the researchers.

A QUICK Q & A ABOUT ULTRAFAST FREQUENCY HOPPING

In this conversation with Connector contributor Eric Smalley, researcher Rabia Tugce Yazicigil, now an assistant professor of electrical and computer engineering at Boston University, describes how the new technology can better secure the Internet of Things.

Q: What are the challenges to protecting wireless communications of the Internet of Things (IoT)?

A: Resource constraints and the massive scale of devices make IoT security hard. Our work specifically addresses a wireless attack scenario — selective jamming denial of service — where the adversary corrupts transmitted messages targeting a single device. Selective jamming is particularly challenging as it conceals the attacker’s identity, unlike broadband wireless jamming.

Researcher Rabia Tugce Yazicigil was the first author on a paper describing the novel transmitter.



Q: In simple terms, can you describe what your ultrafast, low-power, frequency-hopping system is and does?

A: Current packet-level, frequency-hopping protocols are vulnerable to selective jamming because packet durations are long enough to allow the packet to be localized and blocked. The cause of this vulnerability is that the data packet is sent on a single channel with a relatively slow hop period of 612 microseconds. An attacker needs only one microsecond to identify the carrier frequency and block the remainder of the data packet.

To counter this attack, we developed physical-layer security through an ultrafast, bit-level frequency-hopping scheme that sends every data bit on a unique carrier frequency while achieving a one-microsecond hop period.

Another challenging issue is that traditional modulation schemes permit the attacker to selectively overwrite individual bits in a packet once the carrier frequency is localized. We developed a dynamic channel selection scheme that provides data encryption in the physical layer. Even when the full history of transmitted hops is revealed to the attacker, they are not able to predict the location of any future bit.

Q: Who would use your technology?

A: We offer physical-layer security for connectivity of everything. Initially, this could mean securing smart meters that read home utilities, control heating, or monitor the grid. The transmitter could also help secure medical devices, such as insulin pumps and pacemakers. When people start

corrupting the messages of these devices, it starts affecting people's lives. This work has opened the opportunity to address long-standing issues of wireless communication security in multiple industries.

Q: How did you come up with the ideas for the frequency-hopping system?

A: We demonstrated a selective jamming attack against commercial Bluetooth low energy (BLE) devices. To protect against this type of physical-layer attack, we developed an energy-efficient system-level solution. Two key ideas for this work were utilizing the frequency agility of Bulk Acoustic Wave (BAW) devices and using time interleaving to achieve zero dead zones between the hops.

Q: What do you mean when you say that your research approach is “cross-layer optimization from circuits to protocols”?

A: Cross-layer optimization from circuits to protocols means that our research spans the communication stack, and when we develop a new concept we leverage the features of each layer. For example, to extend the ultrafast bit-level frequency-hopping idea to a network of devices, there was a need for a new protocol that would allow our devices to coexist with other devices and existing communication protocols.

Q: What's next in your research?

A: There are several research opportunities to provide end-to-end security through co-development of energy-efficient hardware and protocols. For example, we are currently developing fully-integrated cryptographic terahertz identification tags for authentication in collaboration with Professor Ruonan Han's research group [the Terahertz Integrated Electronics Group in MIT's Microsystems Technology Laboratories (MTL)]. 

“We offer physical-layer security for connectivity of everything. Initially, this could mean securing smart meters that read home utilities, control heating, or monitor the grid. The transmitter could also help secure medical devices, such as insulin pumps and pacemakers.”

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FACULTY AWARDS



Anant Agarwal

Yidan Prize for Educational Development Laureate



Mohammad Alizadeh

Rising Star Award, ACM SIGCOMM
NSF CAREER Award



Saman Amarasinghe

Best Student Paper Award, IEEE International Conference on Big Data
Distinguished Paper Award, ACM SIGPLAN SPLASH Conference



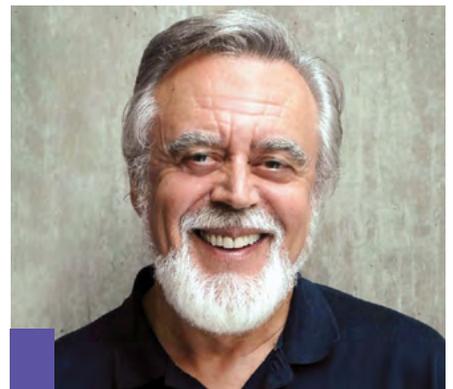
Hari Balakrishnan

Best Instructor Award, MIT HKN (Eta Kappa Nu)



Regina Barzilay

2017 MacArthur Fellow
Fellow, Association for the Advancement of Artificial Intelligence (AAAI)
Fellow, Association for Computational Linguistics (ACL)
Ruth and Joel Spira Award for Excellence in Teaching



Dimitri Bertsekas

John von Neumann Theory Prize, INFORMS



Robert C. Berwick

Jerome H. Saltzer Award for Excellence in Teaching



Sangeeta Bhatia

Catalyst Award, Science Club for Girls
Innovation at the Intersection Award, Economy
Game Changer 365 Award, Women at the Frontier



Tamara Broderick

Army Research Office Young Investigators Program (YIP) Award
NSF CAREER Award
Sloan Research Fellowship



Michael Carbin

NSF CAREER Award



Luca Daniel

Best Paper, IEEE Transactions on Components, Packaging and Manufacturing Technology
Cover-featured paper, *Journal of Magnetic Resonance in Medicine*



Constantinos Daskalakis

Rolf Nevanlinna Prize, International Mathematical Union
Simons Investigator Award



Erik Demaine

Burgess (1952) and Elizabeth Jamieson Prize for Excellence in Teaching



Srini Devadas

Bose Award for Excellence in Teaching
Charles A. Desoer Technical Achievement Award, IEEE Circuits and Systems
Distinguished Alumnus Award, IIT Madras



Dennis M. Freeman

Innovative Seminar Award, Office of the Vice Chancellor
Burgess (1952) and Elizabeth Jamieson Prize for Excellence in Teaching



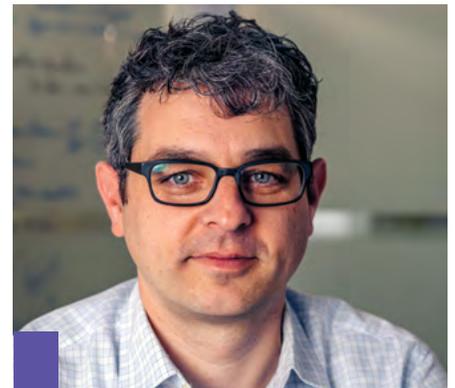
Shafi Goldwasser

Fellow, ACM
Frontiers of Knowledge Award, BBVA Foundation



Martha Gray

Program Award for Culture of Excellence in Mentoring, Harvard Medical School
Memorial Award, Civil Servants Social Security and Services Institute



Thomas Heldt

Distinguished Lecturer, IEEE Engineering in Medicine and Biology Society (EMBS)



Gim P. Hom, Lecturer

Best Advisor Award, MIT IEEE/ACM



Qing Hu

Kenneth J. Button Prize, International Society of Infrared, Millimeter, and Terahertz Waves



Daniel Jackson

Martin Luther King Jr. Leadership Award, MIT



Stefanie Jegelka

DARPA Young Faculty Award
Joseph A. Martore Award for Exceptional Contributions to Education, IDSS
Sloan Research Fellowship
X-Windows Consortium Career Development Assistant Professor



Dina Katabi

ACM Prize in Computing
Honorary Degree, Catholic University of America
Professor Amar G. Bose Research Grant, MIT



Charles Leiserson

Network Systems Award, ACM SIGCOMM



Barbara Liskov

Computer Pioneer Award, IEEE Computer Society
Honorary Doctorate, Technical University of Madrid



Luqiao Liu

William L. McMillan Award, Department of Physics, University of Illinois at Urbana-Champaign
Young Investigator Program (YIP) Grant, U.S. Air Force Office of Scientific Research
Young Scientist Prize in Physics, International Union of Pure and Applied Physics



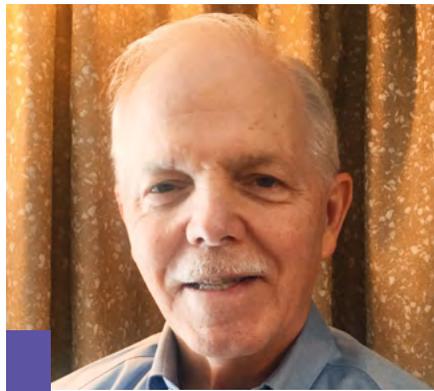
Tomás Lozano-Pérez

Fellow, ACM



Aleksander Madry

Presburger Award for Young Scientists,
European Association for Theoretical
Computer Science



Thomas Magnanti

Singapore's National Day Award



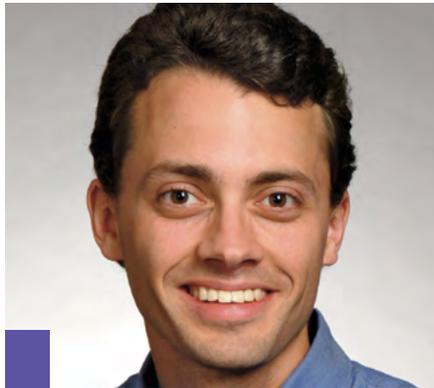
Muriel Médard

Edwin Howard Armstrong Achievement
Award, IEEE Communication Society
Fellow, National Academy of Inventors



Silvio Micali

Fellow, ACM
Frontiers of Knowledge Award, BBVA
Foundation



Rob Miller

Richard M. Caloggero Award



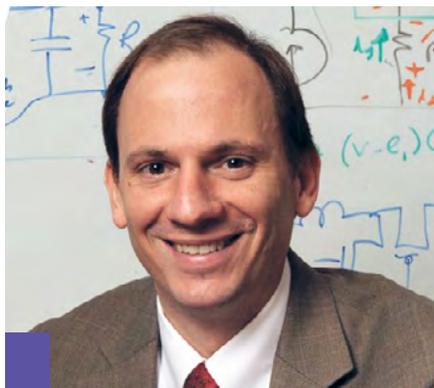
Stefanie Mueller

ACM Doctoral Dissertation Award—Honorable
Mention
EECS Outstanding Educator Award
GI Dissertation Award for Best PhD Thesis in
Computer Science
Outstanding Dissertation Award, ACM SIGCHI



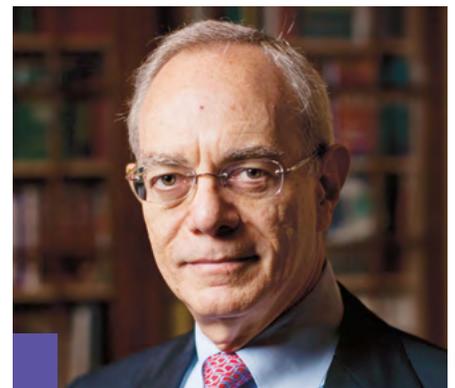
Pablo Parrilo

Fellow, Society for Industrial and Applied
Mathematics (SIAM)



David Perreault

Second-Prize Paper Award, IEEE
Transactions on Power Electronics



L. Rafael Reif

National Academy of Inventors



Ronald Rivest

Frontiers of Knowledge Award, BBVA Foundation Inductee, International Inventors Hall of Fame



Ronitt Rubinfeld

Capers and Marion McDonald Award for Excellence in Mentoring and Advising



Daniela Rus

Pioneer in Robotics & Automation Award, IEEE Robotics & Automation Society (RAS)



Devavrat Shah

Frank Quick Faculty Research Innovation (FRIF) Award, EECS



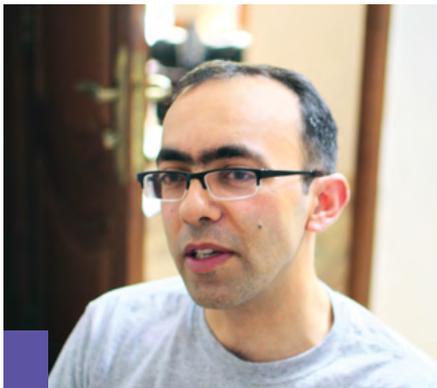
Julian Shun

Early Career Award, U.S. Department of Energy



Justin Solomon

Professor Amar G. Bose Research Grant, MIT



Suvrit Sra

NSF TRIPODS + X Grant



**Joseph Steinmeyer,
Extraordinary Lecturer**

Louis D. Smullin ('39) Award for Excellence in Teaching



Vivienne Sze

Engineering Emmy Award (with JCT-VC team), the Television Academy



Russell Tedrake

Inaugural Paper of the Year Award,
International Journal of Robotics



Chris Terman, Senior Lecturer

Gordon Y Billard Award, MIT



John Tsitsiklis

Honorary Degree, Athens University of Economics
and Business IEEE Control Systems Award
IEEE Control Systems Award
John von Neumann Theory Prize, INFORMS
Saul Gass Expository Writing Award, INFORMS



Caroline Uhler

Joseph A. Martore Award for Exceptional
Contributions to Education, IDSS



Vinod Vaikuntanathan

Harold E. Edgerton Faculty Achievement
Award, MIT



Alan Willsky

IEEE Jack S. Kilby Signal Processing Medal



Gregory Wornell

IEEE Leon K. Kirchmayer Graduate Teaching
Award



Nikolai Zeldovich

Faculty Research Innovation Award (FRIF),
EECS
Mark Weiser Award, ACM SIGOPS

DEPARTMENT HEAD ASU OZDAGLAR MAKES HISTORY

Asu Ozdaglar, the School of Engineering Distinguished Professor of Engineering, recently completed her first year as the head of MIT's Department of Electrical Engineering and Computer Science. She is the first woman to hold that post.

Previously, she served as interim department head after Anantha Chandraksan, Vannevar Bush Professor of Electrical Engineering and Computer Science, became dean of the School of Engineering. Earlier, she was an associate department head. She has also been director of the Laboratory for Information and Decision Systems (LIDS) and associate director of the Institute for Data, Systems, and Society (IDSS).

Ozdaglar has made fundamental contributions to optimization theory, economic and social networked systems, and game theory. Her research in optimization ranges from convex analysis and duality to distributed methods for large-scale systems and optimization algorithms for machine learning. Her work on game theory focuses on adaptive dynamics in networks and large games, and issues of new equilibrium concepts and computation of equilibria. Her research has integrated analysis of social and economic interactions within the study of networks and spans many dimensions of these areas, including the analysis of learning and communication, diffusion and information propagation, influence in social networks, and cascades and systemic risk in economic and financial systems.

Ozdaglar's educational contributions to MIT are equally substantial. She has developed a range of graduate and undergraduate courses, including a graduate-level game theory subject and an undergraduate course on networks that is jointly listed with the Department of Economics. She played a leading role (with EECS Professor Costis Daskalakis and colleagues in MIT's Department of Economics) in launching a new undergraduate major in 6-14: Computer Science, Economics and Data Science. She was the chair for Rising Stars in EECS in 2018, an academic-careers workshop for women postdocs and graduate students, and served as technical chair for Rising Stars 2015.

Most recently, Ozdaglar was named the School of Engineering Distinguished Professor of Engineering in September 2018. The professorship "was established to recognize outstanding contributions in education, research, and service," Chandrakasan said in announcing the appointment. "Professor Ozdaglar's appointment recognizes her exceptional leadership and accomplishments."

Ozdaglar is a past recipient of a Microsoft fellowship, a National Science Foundation (NSF) CAREER Award, and the Donald P. Eckman award of the American Automatic



Professor Asu Ozdaglar
Photo: Lillie Paquette, School of Engineering

Control Council, and she also held the Class of 1943 Career Development Chair. She was the inaugural Steven and Renee Finn Innovation Fellow and received the Ruth and Joel Spira Award for Excellence in Teaching. She served on the Board of Governors of the Control System Society and was an associate editor for *IEEE Transactions on Automatic Control*. She is the inaugural area co-editor for a new area for the journal *Operations Research*, entitled "Games, Information and Networks," and she is the co-author of *Convex Analysis and Optimization* (Athena Scientific, 2003).

Ozdaglar received a bachelor's degree in electrical engineering from the Middle East Technical University, in Ankara, Turkey, in 1996, and masters' and PhD degrees in electrical engineering and computer science from MIT in 1998 and 2003. 

MEET THE ASSOCIATE DEPARTMENT HEADS



Professors Saman Amarasinghe, Joel Voldman, and Nancy Lynch

Three EECS professors joined the department's leadership team in 2018. Saman Amarasinghe and Joel Voldman became associate department heads, while Nancy Lynch was named associate department head for strategic directions, a new post overseeing academic and research initiatives.

"All three are distinguished scholars and dedicated educators whose experience will contribute greatly to shaping the department's future," Asu Ozdaglar, department head and School of Engineering Distinguished Professor of Engineering, said in announcing the appointments.

Saman Amarasinghe is a principal investigator at the Computer Science and Artificial Intelligence Laboratory (CSAIL), where he leads the Commit compiler research group. His group focuses on programming languages and compilers that maximize application performance on modern computing platforms. He also pioneered the application of machine learning for compiler optimization, and he was the co-leader of the Raw architecture project with EECS Professor and edX CEO Anant Agarwal. He was the founder of Determina Inc., a startup based on computer security research pioneered in his MIT research group and later acquired by VMware.

Recently, his work received a best-paper award at the 2017 Association for Computing Machinery (ACM) Object-Oriented Programming, Systems, Languages, and Applications (OOPSLA) conference and a best student-paper award at the 2017 IEEE International Conference on Big Data.

A faculty member since 1997, Amarasinghe served as an EECS education officer and chairs the department's computer science graduate admissions committee. He developed the popular class 6.72 (Performance Engineering of Software Systems) with Charles Leiserson, the Edwin Sibley Webster Professor of Electrical Engineering and Computer Science. Recently, he has created individualized software project classes.

He received a bachelor's degree in electrical engineering and computer science from Cornell University, and a master's degree and PhD in electrical engineering from Stanford University.

Nancy Lynch, the NEC Professor of Software Science and Engineering, heads the Theory of Distributed Systems research group in CSAIL.

She is known for her fundamental contributions to the foundations of distributed computing. Her work applies a mathematical approach to explore the inherent limits on computability and complexity in distributed systems. Her best-

known research is the FLP impossibility result for distributed consensus in the presence of process failures. Other research includes the I/O automata system modeling frameworks. Her recent work focuses on wireless network algorithms and biological distributed algorithms.

Lynch has written or co-written hundreds of research articles. She is the author of the textbook "Distributed Algorithms" and co-author of "Atomic Transactions" and "The Theory of Timed I/O Automata." She is a Fellow of the ACM and of the American Academy of Arts and Sciences, and a member of the National Academy of Science and the National Academy of Engineering. She has received the Dijkstra Prize twice, the van Wijngaarden prize, the Knuth Prize, the Piore Prize, and the Athena Prize.

A faculty member since 1982, Lynch has supervised 30 PhD students and similar numbers of master's-degree candidates and postdoctoral associates, many of whom have themselves become research leaders. She received a bachelor's degree from Brooklyn College and a PhD from MIT, both in mathematics.

Joel Voldman is a professor in EECS and a principal investigator in the Research Laboratory of Electronics (RLE) and the Microsystems Technology Laboratories (MTL). He joined the EECS faculty in 2001.

Voldman's research focuses on developing microfluidic technology for biology and medicine, with an emphasis on cell sorting and stem cell biology. He has developed a host of technologies to arrange, culture, and sort diverse cell types, including immune cells, endothelial cells, and stem cells. Current areas of research include recapitulating the induction of atherosclerosis on a microfluidic chip, and using microfluidic tools to study how immune cells decide to attack tumor cells. He is also interested in translational medical work.

He has co-developed introductory courses in medical technology and interconnected embedded systems. Awards and honors include a National Science Foundation (NSF) CAREER award, an American Chemical Society (ACS) Young Innovator Award, a Bose Fellow grant, MIT's Jamieson Teaching Award, a Louis D. Smullin ('39) Award for Excellence in Teaching, a Frank Quick Faculty Research Innovation Fellowship from EECS, an IEEE/ACM Best Advisor Award, and awards for posters and presentations at international conferences. He received a bachelor's degree in electrical engineering from the University of Massachusetts at Amherst and a master's degree and PhD in electrical engineering from MIT. 

MEET THE DEPARTMENT'S EDUCATION AND UNDERGRADUATE OFFICERS

EECS rounded out its leadership team by appointing three new officers in 2018. Professors Elfar Adalsteinsson and Dennis Freeman became EECS education officers, while Katrina LaCurts became the department's undergraduate officer.

Elfar Adelsteinsson is a professor in EECS and in MIT's Institute for Medical Engineering and Science (IMES). He is also a principal investigator in the Research Laboratory of Electronics (RLE), where he heads the Magnetic Resonance Imaging (MRI) Group. From 2010 to 2016, he served as associate director of the Madrid-MIT M+Visión Consortium, a partnership dedicated to catalyzing change in Madrid's health care innovation ecosystem by accelerating translational research and encouraging entrepreneurship.

He is a member of the College of Fellows of the American Institute for Medical and Biological Engineering and of the International Society of Magnetic Resonance in Medicine. Among other awards and honors, he has received an EECS Frank Quick Faculty Research Innovation Fellowship (FRIF) and a Fulbright Fellowship. He received PhD and master's degrees in electrical engineering from Stanford University and a bachelor's degree in electrical engineering from University of Iceland Reykjavik.

Dennis M. Freeman is Henry Ellis Warren (1894) Professor in EECS and a principal investigator in RLE. His research group pioneered the use of advanced optical methods to measure sound-induced nanometer motions of cells and accessory structures in the inner ear, revealing the critical role of the tectorial membrane in transforming sound to the motions that stimulate the inner ear's sensory receptor cells.

He was previously EECS education officer from 2008 to 2011, and he has also been the department's undergraduate officer and MIT dean for undergraduate education. Among other honors, Freeman has received the Ruth and Joel Spira Award for Excellence in Teaching, the Irving M. London Teaching Award, and the Bose Award for Excellence in Teaching. He is a MacVicar Faculty Fellow and has three times been selected by students as the best academic advisor in EECS. He is a Fellow of the Acoustical Society of America and a member of the IEEE, the American Academy for the Advancement of Science, and the American Society of Engineering Education, among others. He received PhD and master's degrees in electrical engineering and computer science from MIT and a bachelor's degree in electrical engineering from the Pennsylvania State University.



Professor Elfar Adalsteinsson



Professor Dennis M. Freeman



Dr. Katrina LaCurts

Katrina LaCurts is an EECS lecturer who specializes in teaching large undergraduate computer-systems courses. She is also an EECS undergraduate academic advisor, occasionally advises MEng students, and is a member of the Dean's Action Group. She has also taught introductory discrete math to high school students as part of the MIT Women's Technology Program, a four-week summer program allowing young women to explore engineering and computer science, MIT BLOSSOMS, which creates classroom videos on science, technology, engineering, and mathematics (STEM) topics. She was a member of the MIT Teaching and Learning Lab's inaugural faculty cohort. She has received both the HKN (Eta Kappa Nu) Best Instructor Award and the EECS Outstanding Educator Award. She received a PhD in computer science from MIT's Computer Science and Artificial Intelligence Laboratory, a master's degree in computer science from MIT, and a bachelor's degree in computer science and mathematics from the University of Maryland. 🇺🇸

FACULTY RESEARCH INNOVATION FELLOWSHIPS (FRIFS)

EECS awarded Faculty Research Innovation Fellowships (FRIFs) to Professors **Devavrat Shah** and **Nickolai Zeldovich** in 2018.

Shah received a Frank Quick Faculty Research Innovation Fellowship, created through the generosity of EECS alumnus Frank Quick '69, SM '70. Zeldovich received an EECS Faculty Research Innovation Fellowship.

The fellowships were established to recognize midcareer faculty members for outstanding research contributions and international leadership in their fields. The FRIFs provide tenured faculty with resources to pursue new research and development paths, and to make potentially important discoveries through early-stage research.

Shah, a faculty member since 2005, is a member of the Laboratory for Information and Decision Sciences (LIDS) and the Institute for Data, Systems and Society (IDSS). He also directs the Statistics and Data Science Center (SDSC).

His research focuses on statistical inference and stochastic networks. His contributions span a range of areas, including resource allocation in communications networks, inference and learning on graphical models, and algorithms for social data processing including ranking, recommendations, and crowdsourcing. Within the broad context of networks, his work covers a variety of areas across electrical engineering, computer science and operations research.

Shah received a bachelor's degree in computer science and engineering from the Indian Institute of Technology (ITT) Bombay, where he received the President of India Gold Medal, awarded to the best graduating student across all engineering disciplines. He received a PhD in computer science from Stanford University and was awarded the George B. Dantzig Dissertation Award from the Institute for Operations Research and the Management Sciences (INFORMS).

His work has received broad recognition, including a Rising Star Award from the Association for Computing Machinery (ACM) Special Interest Group for the computer systems performance evaluation community (SIGMETRICS) and the Erlang Prize from the Applied Probability Society of INFORMS. He has also received an National Science Foundation (NSF) CAREER Award.

Best-paper prizes include the Best Publication Award from the Applied Probability Society of INFORMS and best-paper awards from the Manufacturing and Service Operations Management Society of INFORMS, ACM SIGMETRICS, and the



Professor Devavrat Shah



Professor Nickolai Zeldovich

Neural Information Processing Systems (NIPS) conference. He was also named a Young Alumni Achiever by IIT Bombay. He founded the machine learning start-up Celect, Inc. which helps retailers with optimizing inventory by accurate demand forecasting.

Zeldovich, a faculty member since 2008, is a member of the Computer Science and Artificial Intelligence Laboratory (CSAIL). His research interests are in building practical secure systems. He has been involved with numerous startup companies including MokaFive (desktop virtualization), PreVeil (end-to-end encryption), and Algorand (cryptocurrency). He received bachelor's and master's degrees in EECS from MIT before receiving a PhD in computer science from Stanford.

Other awards include a Sloan Research Fellowship, an NSF CAREER Award, the Ruth and Joel Spira Award for Excellence in Teaching, the MIT Harold E. Edgerton Faculty Achievement Award, and the Mark Weiser Award from the ACM Special Interest Group in Operating Systems (SIGOPS). 🏆

POLINA GOLLAND NAMED TO HENRY ELLIS WARREN (1894) CHAIR

EECS Professor **Polina Golland** has been appointed to the Henry Ellis Warren (1894) Chair.

“The appointment recognizes Professor Golland’s leadership in medical imaging research, her outstanding mentorship and educational contributions, and her exceptional service to the department,” EECS department head Asu Ozdaglar said in making the announcement.

Golland joined EECS in 2003. She received a PhD in EECS from MIT and bachelor’s and master’s degrees in computer science from Technion, Israel.

She is a principal investigator in the Computer Science and Artificial Intelligence Laboratory (CSAIL) and a faculty member in the Institute for Medical Engineering and Science (IMES). Her primary research interest is in developing novel approaches for medical image analysis and understanding. With her students, she has demonstrated novel approaches to image segmentation, shape analysis, functional image analysis, and population studies. She has also worked on various problems in computer vision, motion and stereo, predictive modeling, and visualization of statistical models.

Jointly with Professors Alan Willsky, Greg Wornell, and Lizhong Zheng, Golland developed and has taught 6.437 (Inference and Information) since 2006. This graduate course exposes the students to fundamental frameworks for statistical inference and relevant connections to information theory. In 2014, Golland and her colleagues introduced the same topics into the undergraduate curriculum via 6.008 (Introduction to Inference). This undergraduate course provides a computational perspective on statistical inference, modeling, and information theory through analytical exercises and computational labs.

Golland has served as an associate editor or a member of the editorial board for the IEEE Transactions on Medical Imaging and IEEE Transactions on Pattern Recognition and Machine Intelligence. She has served on the board of the Medical Image Computing and Computer Assisted Interventions (MICCAI) Society, chaired the Society’s annual meeting in 2014, and was elected a Fellow of the Society in 2016.

Working with colleagues in EECS and IMES, Golland founded Rising Stars in EECS in 2012 and Rising Stars in Biomedical in 2016. The intensive career-development workshops are designed for top women and under-represented minority postdocs and graduate students. The Rising Stars workshops have since been offered in physics, mechanical engineering, and chemical engineering at MIT and at other universities. In 2014, the Electrical and Computer Engineering Department



Professor Polina Golland
Photo: Allegra Boverman

Heads Association (ECEDHA) presented Golland with its Diversity Award in recognition of her work with Rising Stars. (The Rising Stars workshop returned to EECS in October 2018; see coverage elsewhere in this issue.)

She has also received a National Science Foundation (NSF) CAREER Award, the Louis D. Smullin ('39) Award for Excellence in Teaching, the Burgess ('52) & Elizabeth Jamieson Prize for Excellence in Teaching, and an EECS Faculty Research Innovation Fellowship (FRIF).

The Warren Chair is designated for interdisciplinary research leading to application of technological developments in electrical engineering and computer science, with their effect on human ecology, health, community life, and opportunities for youth. It was established in memory of well-known inventor Henry Ellis Warren, class of 1894. EECS Professors Louis Braida and Dennis Freeman also hold Warren chairs. 

PIOTR INDYK NAMED TO THOMAS D. AND VIRGINIA W. CABOT CHAIR

EECS Professor **Piotr Indyk** has been appointed as the Thomas D. and Virginia W. Cabot Professor.

“This appointment recognizes Professor Indyk’s foundational research in the broad area of design and analysis of algorithms with fundamental contributions in high-dimensional computational geometry and in the development of algorithms for massive data sets, as well as outstanding educational contributions and service to the department,” EECS department head Asu Ozdaglar said in making the announcement.

Indyk joined EECS in 2000. He received a PhD in computer science from Stanford University and a Magister degree from Uniwersytet Warszawski (the University of Warsaw) in Poland.

Indyk is a principal investigator in the Computer Science and Artificial Intelligence Laboratory (CSAIL). He is the lead principal investigator on an NSF-supported MIT Institute for Foundations of Data Science (MIFODS) project. His research interests lie in the design and analysis of efficient algorithms. Specific interests include high-dimensional computational geometry, sketching and streaming algorithms, sparse recovery, and machine learning.

He has co-created several courses that bridge algorithms and other areas of EECS, including 6.850 (Geometric Computing), 6.047/6.878 (Genomes, Networks, Evolution) and 6.893 (Algorithms and Signal Processing). He also co-teaches courses on algorithms and sub-linear algorithms.

Among other honors, Indyk has received a National Science Foundation (NSF) CAREER Award, a Sloan Research Fellowship, a Packard Foundation Fellowship, and a Simons Investigator Award in theoretical computer science. He received the Association for Computing Machinery (ACM) Paris Kanellakis Theory and Practice Award for “groundbreaking work on locality-sensitive hashing that has had great impact in many fields of computer science, including computer vision, databases, information retrieval, machine learning, and signal processing.” He is also an ACM Fellow. His work on Sparse Fourier Transform was named one of *MIT Technology Review’s* “10 Breakthrough Technologies” in 2012.

The Thomas D. and Virginia W. Cabot chair, established in 1986, reflects a long and distinguished relationship between the Cabot family and MIT. Thomas Cabot’s grandfather, physician Samuel Cabot, was among the Boston citizens whose efforts led the founding of MIT. His father, Godfrey L. Cabot, a member of the MIT class of 1881 and founder of the company that bears the family name, was a benefactor of the Institute, having established the Godfrey L. Cabot Solar Energy Fund. 🇺🇸



Professor Piotr Indyk

PABLO PARRILO NAMED TO JOSEPH F. AND NANCY P. KEITHLEY CHAIR

EECS Professor Pablo Parrilo has been appointed to the Joseph F. and Nancy P. Keithley Chair.

“This appointment recognizes Professor Parrilo’s foundational research in the broad area of mathematics of information with major contributions in control, optimization, theoretical computer science, quantum computing, and statistical signal processing — as well as his significant teaching and service contributions to the department,” EECS department head Asu Ozdaglar said in announcing the appointment.

Parrilo joined EECS as an associate professor in 2004, becoming a professor in 2008. Previously, he was an assistant professor at the Automatic Control Laboratory of the Swiss Federal Institute of Technology (ETH Zurich) and visiting associate professor at the California Institute of Technology.

He received a PhD in Control and Dynamical Systems (CDS) from the California Institute of Technology in 2000 and an undergraduate degree in electronics engineering from the University of Buenos Aires in 1994.

Parrilo is a principal investigator with the Laboratory for Information and Decision Systems (LIDS) and is affiliated with MIT’s Operations Research Center. His research interests include optimization methods for engineering applications, control and identification of uncertain complex systems, robustness analysis and synthesis, and the development and application of computational tools based on convex optimization and algorithmic algebra to practically relevant engineering problems.

His educational contributions include the creation of the new graduate course 6.256 (Algebraic Techniques and Semidefinite Programming) and the updating of several optimization-related graduate courses. On the undergraduate side, he co-developed an experimental version of 6.003 (Signals and Systems) and 6.036 (Introduction to Machine Learning).

Awards and honors include the Donald P. Eckman Award from the American Automatic Control Council, the Society of Industrial and Applied Mathematics (SIAM) Activity Group on Control and Systems Theory (SIAG/CST) Prize, the IEEE Antonio Ruberti Young Researcher Prize, and the Farkas Prize from the Optimization Society of the Institute for Operations Research and the Management Sciences (INFORMS).

Parrilo is an IEEE Fellow. He was one of 28 researchers worldwide named to the SIAM Fellows Class of 2018, a distinction given in recognition of his “foundational contributions to algebraic methods in optimization and engineering.”



Professor Pablo Parrilo

The Joseph F. and Nancy P. Keithley chair, originally created as a career-development chair, became a senior faculty professorship in 1990. MIT alumnus Joseph F. Keithley received a bachelor’s degree in 1937 and a master’s degree in 1938, both in electrical engineering, and then went on to found Keithley Instruments. 

ROB MILLER NAMED AS DISTINGUISHED PROFESSOR IN ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

EECS Professor Rob Miller has been appointed as the inaugural Distinguished Professor in Electrical Engineering and Computer Science.

“This newly endowed chair was established to recognize faculty with a strong interest in K-12 education and its relation to teaching and research in computer science education,” EECS department head Asu Ozdaglar said. “The appointment recognizes Professor Miller’s leadership in the area of computer science education and research as well as his outstanding mentorship and educational contributions.”

Miller is internationally well-known in the field of human-computer interaction (HCI), in which he has pioneered techniques for intelligent text editing using many cursors at once, developed new approaches for end-user scripting of web pages and desktop graphical interfaces, and made seminal contributions in crowdsourcing, particularly in orchestrating small contributions from many people to solve a complex problem.

His work on crowdsourcing and HCI has found new applications in computer science education, where organizing small contributions from a crowd of students can turn the size of a massive online or residential course into a virtue rather than a curse. Much of his group’s current work focuses on tools and techniques for teaching large programming courses, including clustering and visualizing many solutions to the same problem in order to identify common mistakes, find unusual but good solutions, and speed up grading.

Miller also makes substantial contributions to the Institute’s educational mission, Ozdaglar said. He has created or co-created three courses in software design: 6.031 (Software Construction, originally 6.005); 6.813 (User Interface Design and Implementation); and 6.811 (Principles and Practice of Assistive Technology). He has also deployed 6.005 onto MITx, where it formed two modules of the Foundations of Computer Science XSeries. For his teaching contributions, he has received the Louis D. Smullin (’39) Award for Excellence in Teaching, the Burgess (’52) & Elizabeth Jamieson Prize for Excellence in Teaching, the MacVicar Faculty Fellowship, and the Teaching with Digital Technology Award.

As a former EECS education co-officer, Miller created a predictive model of student registration that helps distribute more than 200 teaching assistants (TAs) fairly across the department’s courses, as well as a calendar tool that allows for better coordination of quizzes and deadlines between large courses. 



Professor Rob Miller

DENNIS M. FREEMAN NAMED TO HENRY ELLIS WARREN (1894) CHAIR

EECS Professor Dennis M. Freeman has been appointed to the Henry Ellis Warren (1894) Chair.

The appointment recognizes Freeman's leadership in cochlear mechanics research, his outstanding mentorship and educational contributions, and his exceptional service to the Institute, department officials said.

The Warren Chair is designated for "interdisciplinary research leading to application of technological developments in electrical engineering and computer science, with their effect on human ecology, health, community life, and opportunities for youth." It was established in memory of Henry Ellis Warren, who was one of the Institute's first graduates in electrical engineering. Warren was best known for the invention (among his 135 patents) of the electrical clock and its associated self-starting synchronous motor; he was also noted for convincing power companies to more tightly regulate the frequency on their nominally 60Hz waveform, which eventually allowed the interconnection of regional power systems to form today's continental-scale power grids. Professors Louis D. Braida and Polina Golland are also Warren chair holders, and Professor George C. Verghese held the chair as well until his transition to professor post-tenure status.

Freeman has been active in undergraduate teaching since joining the faculty in 1995. His early teaching focused on 6.003 (Signals and Systems) and 6.021 (Quantitative Physiology: Cells and Tissues). He has contributed to the development and teaching of 6.01 (Introduction to EECS I), which more than 3,000 students have taken.

He helped develop the Advanced Undergraduate Research Opportunities Program, better known as SuperUROP, and has frequently taught 6.UAR, the accompanying research course. (See recent SuperUROP coverage elsewhere in this issue.) He also developed and currently teaches the Mens et Manus freshman advising seminar, in which students use modern prototyping methods (such as 3D printing and laser cutting) to make devices that build on required subjects such as calculus, mechanics, and electricity and magnetism.

Freeman's numerous teaching awards include the Ruth and Joel Spira Award for Excellence in Teaching, the Irving M. London Teaching Award, and the Bose Award for Excellence in Teaching. He has been a MacVicar Faculty Fellow, and has three times been selected by students as the best academic advisor in EECS.

Freeman is currently an EECS education officer. Previously, he served as the department's undergraduate officer and MIT dean for undergraduate education. He has also served



Professor Dennis M. Freeman

on or chaired many Institute committees, including the Committee on the Undergraduate Program, the Committee on Curricula, the Task Force on the Undergraduate Commons, the Committee on Global Educational Opportunities for MIT, the Educational Commons Subcommittee, the Corporation Joint Advisory Committee, the Task Force on Planning, and the Task Force on the Future of MIT Education. 

FOUR EECS FACULTY MEMBERS RECEIVE PROMOTIONS

Four EECS faculty members received significant promotions in 2018.

Constantinos Daskalakis and **Nickolai Zeldovich** were each promoted to full professor of electrical engineering and computer science, while **Ruonan Han** and **Caroline Uhler** were each promoted to associate professor without tenure (AWOT). All the appointments were effective July 1, 2018.

Constantinos Daskalakis is a leading theoretical computer scientist working in a variety of areas involving foundations and applications of probability, including algorithmic game theory, mechanism design, and statistical sampling. He received a PhD from the University of California at Berkeley in 2008 and joined MIT in 2009 after a one-year postdoctoral position at Microsoft Research. He is a member of the Computer Science and Artificial Intelligence Laboratory (CSAIL), and he was granted tenure in 2015.

Daskalakis began his research career working in the field of algorithmic game theory. His most notable result in that area says that Nash equilibria, which describe stable configurations of competitive multi-player games, cannot be computed efficiently. After obtaining a series of related results, he began working in mechanism design, where he obtained another breakthrough: he showed that the general problem of mechanism design, which allows a system to achieve desired results in the face of strategic, possibly dishonest participants, can be reduced to the simpler problem of algorithm design, in which the participants are assumed to be honest.

More recently, Daskalakis worked on a long-standing problem from economic theory: optimal pricing for multiple items. Again, he obtained a breakthrough result, this one providing a mathematical characterization of the structure of optimal solutions. He has also been pioneering new methods for discerning properties of unknown probability distributions by using sampling.

Among other honors, he has received a Game Theory and Computer Science Prize, an Association for Computing Machinery (ACM) Doctoral Dissertation Award, a Society for Industrial and Applied Mathematics (SIAM) Outstanding Paper Prize, and a Vatican Giuseppe Sciacca Foundation Research and Development Award. At MIT, he has taught many courses in algorithms, probability, game theory, inference, and data science, and received the Ruth and Joel Spira Award for Excellence in Teaching.

Nickolai Zeldovich received a PhD from Stanford University in 2008 and, after a short postdoctoral appointment at Stanford, joined MIT later that year. He was granted tenure in 2014.

Zeldovich, also a CSAIL member, works on improving the state of computer-system security and on enabling new applications that might not be deployed today because of security concerns. To that end, he has worked on a variety of types of systems, including operating systems and distributed systems that avoid security vulnerabilities, systems that guarantee security even in the face of programmer errors, systems that recover gracefully from intrusions, systems that run applications on encrypted data, and systems that hide the identities of communicating parties.

Recently, he has also been developing rigorous techniques for finding security vulnerabilities in code or proving their absence, as well as building new secure applications such as cryptocurrencies.

Among other honors, he has received a Sloan Research Fellowship, a National Science Foundation (NSF) CAREER Award, and an MIT Harold E. Edgerton Faculty Achievement Award. In February 2018, he was one of two EECS professors to receive the department's Faculty Research Innovation Fellowship (FRIF), an award that recognizes midcareer faculty members for outstanding research contributions and international leadership and provides them with resources to pursue new research and development. At MIT, he has taught many different courses in systems and security, and has also received the Ruth and Joel Spira Award for Excellence in Teaching.

Ruonan Han received a PhD in electrical engineering from Cornell University in January 2014. After a short stint as a research scientist at Cornell, he joined MIT as an assistant professor in July 2014, and he is also a core faculty member of the Microsystems Technology Laboratory (MTL). His work focuses on pushing the fundamental limits of chip-scale electronics and exploring new application opportunities in the realms of sensing and communications. In particular, he is pursuing critical problems in the important "terahertz gap" (0.1-10 THz).

Han's work has generated multiple records in the performance metrics of silicon-based THz circuits, including the highest radiated power and the highest detection sensitivity. In addition, his group invented a new sensor architecture that maintains high efficiency across a scalable, broad bandwidth. His group also demonstrated new applications of THz chips beyond traditional wireless radio and non-invasive imaging: molecular spectroscopy with high specificity, ultra-broadband inter-chip link through a THz dielectric waveguide, and most recently, fully-electronic timekeeping with a molecular clock.



Professor Constantinos Daskalakis

Professor Nickolai Zeldovich

Professor Ruonan Han

Professor Caroline Uhler

Han’s awards include an NSF CAREER Award and best student paper awards at the IEEE Custom Integrated Circuits Conference (CICC) and IEEE Radio Frequency Integrated Circuits (RFIC) Symposium. He also received Cornell’s award for the best PhD thesis. At MIT, he has taught multiple courses in circuits, and contributed to the development of other courses in that subject. He served as the workshop chair of the 2016 IEEE International Wireless Symposium and is a steering-committee member for the 2019 IEEE International Microwave Symposium, the flagship conference for the microwave theory and technique society.

Caroline Uhler received a PhD in statistics from the University of California at Berkeley in 2011. After serving as an assistant professor at IST Austria, she joined MIT as an assistant professor of EECS and a core faculty member of the Institute for Data, Systems, and Society (IDSS).

Uhler’s primary expertise is in the general area of algebraic statistics, a field that focuses on the application of algebra, algebraic geometry, graph theory, optimization and combinatorics to statistical modeling. This broad expertise enables her to produce new paradigms and algorithms for the analysis of large heterogeneous data sets that arise in various applications. Her work to date has broken new ground on providing a systematic approach to studying graphical models. In her PhD work, she initiated the study of Gaussian graphical models using algebraic methods and introduced hyperbolic exponential families as a general class of graphical models that share the nice computational properties of Gaussian models.

Uhler’s awards include a Sofja Kovalevskaja Award, a Sloan Research Fellowship, and an NSF CAREER Award. She also received the Joseph A. Martore Award for Exceptional Contributions to Education from IDSS. She was a plenary speaker on the subject of algebraic statistics during the 2017 SIAM Conference on Applied Algebraic Geometry.

She has developed two courses at MIT, one of which serves as the capstone class for the minor in statistics. She serves on the EECS admissions committee and the Broad Institute Fellows selection committee, and she was an organizer of the joint conference between MIT, Harvard, and Microsoft for Women in Data Science. 

FIVE EECS FACULTY MEMBERS RECEIVE TENURE FROM MIT

Five EECS faculty members are among seven from the School of Engineering who received tenure from MIT in 2018. They are **Adam Chlipala, Dirk Englund, Yury Polyanskiy, David Sontag,** and **Vinod Vaikuntanathan**.

"I am proud to announce this year's cohort of newly tenured faculty in the School of Engineering," said Anantha Chandrakasan, dean of the School of Engineering and Vannevar Bush Professor of Electrical Engineering and Computer Science. "Their work as scholars and educators is inspiring to our entire community. We will benefit immensely from their work."

Following are profiles of the newly tenured EECS faculty members:

Adam Chlipala is a leader in the emerging area of integrated software design and verification. His contributions include building general computational infrastructure (based on the Coq proof-management system) to support programming, formal verification, and automatic code generation, as well as applications to verification of many types of software and hardware systems.

Specific contributions include the Bedrock system for specifying and verifying software designs, the Fiat framework for automatic code generation, the FSCQ project for verifying file systems, the Kami system for verifying hardware designs, and the Fiat elliptic curve cryptography library. Google recently adopted Chlipala's Fiat cryptographic library for its Chrome browser, and his formal specification for the RISC-V processor was adopted as the official specification for the RISC-V instruction set architecture. He is a principal investigator in the Computer Science and Artificial Intelligence Laboratory (CSAIL).

Chlipala helped develop the new undergraduate course 6.009 (Fundamentals of Programming), developed a new graduate course 6.820 (Foundations of Program Analysis), and actively participates in EECS graduate admissions. He has received a National Science Foundation (NSF) CAREER Award, a Symposium on Operating System Principles (SOSP) best-paper award, and two *Communications of the Association for Computing Machinery* (CACM) research highlights.

In his research, **Dirk Englund** focuses on developing solid-state photonic and quantum devices and systems and their use in quantum computation, communications, and sensing. His work emphasizes leveraging deep insight in quantum information theory and optics to develop engineered systems that dramatically advance the field. His stated vision is ambitious:

to create the quantum internet, where entanglement is distributed worldwide. Significant contributions range from achieving record performance with a practical high-dimensional quantum key distribution scheme to performing quantum transport simulations using photonic integrated circuits. He leads the Quantum Photonics Laboratory in the Research Laboratory of Electronics (RLE).

Englund has taught a variety of EECS classes, including 6.01 (Introduction to EECS), 6.UAT (Oral Communication), and 6.UAR (Seminar in Undergraduate Research, the SuperURO course). He also helped create the EECS Communications Lab, which provides resources for graduate students for oral and written communications, and, with Vinod Vaikuntanathan, co-directs Masterworks, the department's annual celebration of research leading to the SM and MEng degrees. His awards include a Sloan Research Fellowship in Physics, the Presidential Early Career Award for Scientists and Engineers, and the Optical Society of America Adolph Lomb Medal, the top award for a young researcher in optics.

Yury Polyanskiy is a well-known theorist who works on information processing systems that arise in communication, control, and learning. He is widely known for his pioneering work on finite blocklength information theory. His work developed fundamental results in non-asymptotic information theory, providing tight lower and upper bounds for the capacity of a given blocklength. He also has important contributions in a broad set of areas including properties of information measures, discrete geometry and combinatorics, and statistical learning theory. The tools and relations he developed for information measures enabled him to settle long-standing conjectures in network information theory and address fundamental questions in control and high-dimensional statistics.

Polyanskiy is a member of the Laboratory for Information and Decision Sciences (LIDS), the Institute for Data, Systems, and Society (IDSS), and the Statistics and Data Science Center (SDSC). He has taught the undergraduate courses 6.02 (Introduction to EECS) and 6.UAR. He is currently co-developing a new foundation-level class, 6.S077 (Introduction to Data Science). He also teaches the graduate classes 6.441 (Information Theory) and 6.436 (Fundamentals of Probability), and he co-developed a new graduate class, 6.265 (Tools of Discrete Probability).

Awards include an NSF CAREER Award, the IEEE Information Theory best-paper award, IEEE International Symposium on Information Theory (ISIT) best student-paper awards (twice), and the Jerome H. Saltzer Award for Excellence in Teaching.



Professor Adam Chlipala



Professor Dirk Englund



Professor Yuri Polyanskiy



Professor David Sontag



Professor Vinod Vaikuntanathan

David Sontag focuses on research in machine learning and applying machine learning to health care. In machine learning, he focuses on graphical models, which provide a mathematically rigorous and computationally efficient way to represent dependencies between a hidden (latent) structure and observations. His contributions include new highly efficient algorithms for learning, inference, and prediction with graphical models from real-world data, and theoretical results in a form of error bounds and correctness proofs that establish a new framework for theoretical analysis of approximate and exact learning and inference in graphical models.

Sontag is a pioneer in applying machine learning expertise to health care, where he has significantly advanced the state of the art in building predictive models from electronic medical records. His expertise in clinical decision making has led him to build novel formulations of machine-learning problems. The analytical tools and algorithms he develops to solve those problems are advancing machine-learning fundamentals and having an impact beyond health care.

Sontag is also the Hermann L. F. von Helmholtz Career Development Assistant Professor in the Institute for Medical Engineering and Science (IMES) and a principal investigator in CSAIL. His honors include an NSF CAREER Award, faculty awards from Google, Facebook, and Adobe, several best-paper awards, and the EECS George M. Sprowls Award for Best PhD Thesis.

Vinod Vaikuntanathan, a leader in theoretical security, focuses on techniques for storing, accessing, and computing with encrypted data. His best-known work is on Fully Homomorphic Encryption, Functional Encryption, and Program Obfuscation, among others. His work involves establishing clear

mathematical definitions of security properties, identifying key hardness assumptions on which to base security claims, devising new algorithms, and proving their security properties. Most of his work uses Lattice-Based Cryptography, which is based on hardness assumptions for problems involving integer lattices; such assumptions might be justified even in a future with powerful quantum computers. He is a principal investigator in CSAIL.

Vaikuntanathan regularly teaches 6.006 (Introductions to Algorithms) and 6.046 (Analysis of Algorithms), and also teaches graduate cryptography courses. He has served on the EECS graduate admissions committee and, with Dirk Englund, co-directs the department's annual EECS Masterworks poster session.

His awards include an NSF CAREER Award, a Sloan Research Fellowship, a Microsoft Research faculty fellowship, and an EECS Ruth and Joel Spira Award for Excellence in Teaching. Most recently, in April 2018, he received MIT's annual Harold E. Edgerton Award for Faculty Achievement, presented to junior faculty for outstanding research, teaching, and service.

The other two School of Engineering faculty members to receive tenure were Ken Kamrin from the Department of Mechanical Engineering and Qiqi Wang from the Department of Aeronautics and Astronautics. 

NEW FACULTY

Since *Connector's* last issue, EECS has welcomed nine new faculty members:



Manya Ghobadi joined EECS as an assistant professor in October 2018. She received a PhD in computer science from the University of Toronto and a bachelor's degree in computer engineering from the Sharif University of Technology. Before coming to MIT, she was a researcher at the Microsoft Research Mobility and Networking group and a software engineer at Google. A computer systems researcher with a networking focus, she has worked on a broad set of topics, including data-center networking, optical networks, transport protocols, network measurement, and hardware-software co-design. Many of the technologies she has helped develop are part of real-world systems at Microsoft and Google. She was recognized as an N2Women Rising Star in networking and communications. Her work has won the best dataset award, Google research excellent-paper award (twice), and the Association for Computing Machinery (ACM) Internet Measurement Conference best-paper award.



Song Han joined EECS as an assistant professor in July 2018. He received a master's degree and PhD in electrical engineering from Stanford University. His research focuses on energy-efficient deep learning at the intersection of machine learning and computer architecture. Han proposed the deep compression algorithm, which can compress neural networks by 17 to 49 times while fully preserving prediction accuracy. He also designed the first hardware accelerator that can perform inference directly on a compressed sparse model, which results in significant speed increases and energy saving. His work has been featured by O'Reilly, TechEmergence, and *The Next Platform*, among others. Han has won best-paper awards at the International Conference on Learning Representations and the International Symposium on Field-Programmable Gate Arrays.



Phillip Isola joined EECS as an assistant professor in July 2018. He received a bachelor's degree in computer science from Yale University and a PhD in brain and cognitive sciences from MIT. Before returning to MIT, Isola was a fellow at OpenAI. He studies visual intelligence from the perspective of both minds and machines. He received a National Science Foundation (NSF) graduate fellowship as well as an NSF postdoctoral fellowship.



Tim Kraska joined EECS as an associate professor in January 2018. Previously an assistant professor of computer science at Brown University, he received a PhD from ETH Zurich, then spent three years as a postdoc in the AMPLab at the University of California at Berkeley, where he worked on hybrid human-machine database systems and cloud-scale data management systems. He focuses on building systems for interactive data exploration, machine learning, and transactional systems for modern hardware, especially the next generation of networks. Kraska was recently selected as an Alfred P. Sloan Research Fellow in computer science. He has also received an NSF CAREER Award, a Young Investigator Program award from the U.S. Air Force Office of Scientific Research, two Very Large Data Bases conference best-demo awards, and a best-paper award from the IEEE International Conference on Data Engineering.



Farnaz Niroui joined EECS as an assistant professor in November 2018. She received PhD and master's degrees in electrical engineering from MIT and a bachelor's degree in nanotechnology engineering from the University of Waterloo. Before returning to MIT, she was a Miller Postdoctoral Fellow at UC Berkeley. Her research integrates electrical engineering with materials science and chemistry to develop hybrid nanofabrication techniques to enable precise yet scalable processing of nanoscale architectures capable of uniquely controlling light-matter interactions, electronic transport, and exciton dynamics to engineer new paradigms of active nanoscale devices. During her graduate studies, Niroui was a recipient of the Engineering Research Council of Canada scholarship. She was selected for the Rising Stars in EECS academic careers workshop for women at MIT in 2015 and at Carnegie Mellon University in 2016, and she was among the technical co-chairs for the most recent Rising Stars event at MIT in October 2018 (see coverage elsewhere in this issue).



Kevin P. O'Brien joined EECS as an assistant professor in July 2018. He earned a bachelor's degree in physics from Purdue University and a PhD in physics from UC Berkeley. He joined the Quantum Nanoelectrics Lab (Siddiqi Group) at UC Berkeley as a postdoctoral researcher to lead development of multiqubit quantum processors. His work has appeared in top journals, including *Science*, *Nature Materials*, and *Nature Communications*, among others. He has been an NSF Graduate Fellow. His research bridges nonlinear optics, metamaterials, and quantum engineering.



Arvind Satyanarayan joined EECS as an assistant professor in July 2018. He received a bachelor's degree from the University of California at San Diego and a master's degree from Stanford — both in computer science — and a PhD in computer science from Stanford, working with the University of Washington Interactive Data Lab. Before coming to MIT, Satyanarayan was a postdoctoral researcher at Google Brain, working on improving the interpretability of deep-learning models through visualization. He focuses on developing new declarative languages for interactive visualization and leveraging them in new systems for visualization design and data analysis. His work has also been deployed on Wikipedia to enable interactive visualizations within articles. Satyanarayan's research has been recognized with a Google PhD fellowship and best-paper awards at the IEEE InfoVis and the ACM Computer-Human Interaction conference.



Julian Shun joined EECS as an assistant professor in September 2017. He received a bachelor's degree in computer science from UC Berkeley, and a PhD in computer science from Carnegie Mellon University. Before coming to MIT, he was a postdoctoral Miller Research Fellow at UC Berkeley. Shun's research focuses on the theory and practice of parallel algorithms and programming. He is particularly interested in designing algorithms and frameworks for large-scale graph analytics. He is also interested in parallel algorithms for text analytics, concurrent data structures, and methods for deterministic parallelism. Shun received the ACM doctoral dissertation award, the CMU School of Computer Science doctoral dissertation award, a Facebook graduate fellowship, and a best-student-paper award at the Data Compression Conference.



Suvrit Sra joined EECS and the Institute for Data, Systems and Society (IDSS) as an assistant professor in January 2018. He was a principal research scientist in the Laboratory for Information and Decision Systems (LIDS) at MIT. He received a PhD in computer science from the University of Texas at Austin in 2007. Before joining LIDS, he was a senior research scientist at the Max Planck Institute for Intelligent Systems in Tübingen, Germany. He has also held visiting faculty positions at UC Berkeley and Carnegie Mellon. His research bridges areas such as optimization, matrix theory, geometry, and probability with machine learning. More broadly, he is interested in data-driven questions within engineering, science, and health care. His work has won several awards at machine learning venues, as well as an Outstanding Paper Award from the Society of Industrial and Applied Mathematics (SIAM). He founded the OPT (Optimization for Machine Learning) series of workshops at the Neural Information Processing Systems conference, which he has co-chaired since 2008; he has also edited a popular book with the same title (MIT Press, 2011).

REMEMBERING PROFESSOR EMERITUS ALAN MCWHORTER, 1930-2018

Long-time EECS professor and Lincoln Laboratory division head is best known for research on transistors, lasers, and masers.

Alan L. McWhorter, a longtime professor in MIT's Department of Electrical Engineering and Computer Science (EECS) and an administrator and researcher at MIT Lincoln Laboratory, has died in New Orleans, Louisiana. He was 87.

His family said his death on July 11, 2018, was unexpected despite some recent health problems. A memorial service will be held at a later date.

McWhorter is best known for his research in electronic and quantum devices including transistors, lasers, and masers. In 1955, he developed the McWhorter model for low-frequency flicker (or $1/f$) noise caused by surface effects in semiconductor devices. The model, sometimes called "the McWhorter effect," continues to be widely cited today. In the mid-1960s, he received three patents related to semiconductors.

However, according to MIT colleague Paul Penfield Jr., his range of interests was broader and extended in many dimensions. "Al's lesser-known but still pioneering work included aspects of control systems, power semiconductors, infrared detection, and optical communications," said Penfield, an emeritus professor and former EECS department head. "But besides his technical breadth, he understood both the theoretical and experimental sides of engineering, cared about both the pedagogy and applications of various technologies, and promoted short-term applied research along with long-range curiosity-driven research."

Long legacy at MIT

Born in Crowley, Louisiana, on Aug. 25, 1930, McWhorter began his education in New Orleans at Tulane University's School of Engineering, then transferred to the University of Illinois at Urbana-Champaign, receiving a bachelor's degree in electrical engineering in 1951. He received an ScD degree in electrical engineering from MIT in 1955.

McWhorter joined the MIT Department of Electrical Engineering as an assistant professor in 1959, served as an associate professor from 1960 to 1966, and as a full professor until he retired in 1996. During his time with EE (now EECS), he supervised more than 30 students' work on their master's, PhD, and ScD theses. With a generous donation, he established a fellowship fund, the Alan L. McWhorter (1955) Fund, to support graduate students studying electrical engineering.

McWhorter was also affiliated with the Solid State Division at MIT Lincoln Laboratory for more than 40 years, beginning as a



Professor Alan L. McWhorter in 1958
Photo: Courtesy of Lincoln Laboratory

staff member in 1955. He served as assistant division head and associate head between 1962 and 1965, when he was named to head the division. He served as division head for 29 years, becoming a Lincoln Laboratory Fellow in 1994 and retiring in 1996.

"Al was a warm, generous, and inspiring colleague," recalled Erich Ippen, a principal investigator at MIT's Research Laboratory of Electronics (RLE) and a professor emeritus of both electrical engineering and physics. "As an early leader in quantum electronics, he was a valuable mentor for us younger researchers in that area on campus as well as at Lincoln Lab."

Frederick Leonberger knew McWhorter in both MIT roles. "I had the good fortune of having Al as my doctoral thesis advisor.

His insightful guidance and high standards not only inspired me in my research, but also provided an excellent model for conducting and managing the research process,” said Leonberger, who is now a principal with EOvation Advisors. “At Lincoln Laboratory, where I subsequently worked, his leadership — as well as the range of research topics he had expertise in and contributed to — provided a role model of technical excellence for the staff, and helped enable the many important technical achievements of the division over the years.”

Many MIT colleagues still recall that, in 1969, McWhorter was involved in a near-fatal collision in Arlington, Massachusetts, sustaining a skull fracture, a concussion, eye and facial injuries, and many broken bones. But four months later, after seven operations and multiple setbacks, he walked out of Massachusetts General Hospital, returning to work at MIT soon after. He also returned to hiking and mountain-climbing, beginning with a trip to the Grand Tetons one year after his release from the hospital.

Patent particulars

McWhorter received his first two patents, both for semiconductor switching matrixes, in 1963 and 1964, at a time when researchers were experimenting with a variety of ways for using semiconductors in computers. The patents describe the development of the cryosar, one of the early semiconductor memory devices. Semiconductor memory (such as RAM) is now ubiquitous in electronics.

The third, and arguably most historically significant patent, came in 1966. It reflected McWhorter’s involvement as a member of one of three teams that had nearly simultaneously demonstrated the first semiconductor laser (then called an infrared maser). Today, semiconductor lasers are used in devices ranging from DVD players to laser pointers to printers to tattoo-removal devices.

Professional recognition

In 1958, McWhorter and two colleagues received the National Electronics Conference Annual Award for their technical paper on solid-state masers.

McWhorter was also a long-time member of the IEEE, a leading technical professional organization. In 1968, he was named an IEEE Fellow, a distinction reserved for select members with extraordinary accomplishments. The IEEE recognized McWhorter “for contributions to control theory and its applications to switch power systems and image processing.” In 1971, McWhorter received the IEEE David Sarnoff Award, which recognizes exceptional work in electronics, “for outstanding contributions leading to a better understanding of semiconductor devices.” In 2000, he won an IEEE Third Millennium Medal “for contributions to control theory and its applications to switch power systems and image processing.” He was one of just 45 members of the IEEE Electron Devices Society to be so honored.

In 1993, he was elected to the National Academy of Engineering for “outstanding research and technical leadership in the

“Al’s lesser-known but still pioneering work included aspects of control systems, power semiconductors, infrared detection, and optical communications. He understood both the theoretical and experimental sides of engineering, cared about both the pedagogy and applications of various technologies, and promoted short-term applied research along with long-range curiosity-driven research.”

—Paul Penfield Jr., an emeritus professor and former EECS department head.

fields of quantum electronics and solid-state devices.” He was also a longtime fellow of the American Physical Society, and a member of the scientific and engineering societies Sigma Xi, Tau Beta Pi, and HKN (Eta Kappa Nu).

McWhorter also authored or co-authored dozens of scientific articles and hundreds of reports, contributed to several books, and served as an editor on two IEEE publications.

Professor emeritus

After retiring in 1996, he returned to the New Orleans area and again began participating in Tulane activities, such as the Friends of Music, the Summer Lyric Theatre, and the Emeritus Club and Educational Conference offerings of the Alumni House. McWhorter is survived in the New Orleans area by niece Patricia McWhorter (Peter C. Broussard); nephews David McWhorter (Lisa) and Steven McWhorter (Renee), and six grandnieces: Olivia Broussard (Lucien Weiss); Allyson McWhorter; Brindley McWhorter; Rebecca McWhorter Ruegge (Gene); Elizabeth McWhorter Guillory (Dakota); and Emily McWhorter Menendez (Colin).

Memorial gifts

Gifts in memory of Alan McWhorter may be made to MIT via the Alan L. McWhorter (1955) Fund, account #3304350. Credit-card gifts can be made at giving.mit.edu/alan-mcwhorter. Checks should be made payable to MIT and mailed to: MIT Memorial Gifts Office, 600 Memorial Drive, Room W98-500, Cambridge, MA 02139. 

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MIT LAUNCHES URBAN SCIENCE/COMPUTER SCIENCE MAJOR

The interdisciplinary undergraduate program combines urban planning and computer science.

By the School of Architecture + Planning and the School of Engineering

Photo: Christopher Harting

Urban settlements and technology around the world are co-evolving as flows of population, finance, and politics are reshaping the very identity of cities and nations. Rapid and profound changes are driven by pervasive sensing, the growth and availability of continuous data streams, advanced analytics, interactive communications and social networks, and distributed intelligence. At MIT, urban planners and computer scientists are embracing these exciting new developments.

The rise of autonomous vehicles, sensor-enabled self-management of natural resources, cybersecurity for critical infrastructure, biometric identity, the sharing or “gig”

economy, and continuous public engagement opportunities through social networks and data and visualization are a few of the elements that are converging to shape our places of living.

In recognition of this convergence and the rise of a new discipline bringing together the Institute’s existing programs in urban planning and computer science, MIT has launched a new undergraduate degree, the bachelor of science in urban science and planning with computer science (Course 11-6).

The new major jointly resides in and is administered by EECS and the Department of Urban Studies (DUSP).

Combining urban planning and public policy, design and visualization, data analysis, machine learning, artificial intelligence, pervasive sensor technology, robotics, and other aspects of both computer science and city planning, the program reflects how urban scientists are making sense of cities and urban data in ways never before imagined — and using what they learn to reshape the world in real time.

“The new joint major will provide important and unique opportunities for MIT students to engage deeply in developing the knowledge, skills, and attitudes to be more effective scientists, planners, and policy makers,” says Eran Ben-Joseph, head of DUSP. “It will incorporate STEM education and research with a humanistic attitude, societal impact, social innovation, and policy change — a novel model for decision making to enable systemic positive change and create a better world. This is really unexplored, fertile new ground for research, education, and practice.”

The goal of the program is to train undergraduates in the theory and practice of computer science and urban planning and policy-making including ethics and justice, statistics, data science, geospatial analysis, visualization, robotics, and machine learning.

“The new program offers students an opportunity to investigate some of the most pressing problems and challenges facing urban areas today,” says Asu Ozdaglar, EECS department head. “Its interdisciplinary approach will help them combine technical tools with fundamental skills in urban policy to create innovative strategies and solutions addressing real-world problems with great societal impact.”

Although this field draws on existing disciplines, the combination will shape a unique area of knowledge. Practitioners are neither computer scientists nor urban planners in a conventional sense, but represent new kinds of actors with new sets of tools and methodologies. Already, in areas as diverse as transportation, public health, and cybersecurity, researchers and practitioners at MIT are pioneering work along these lines, demonstrating the potential for collaborative efforts.

“Every now and then, the world puts in front of us new problems that require new tools and forms of knowledge to address them,” says Hashim Sarkis, dean of the School of Architecture and Planning (SA+P). “The growing challenges that cities are facing today has prompted us to develop this new major in urban science. We are combining the tools of AI and big data with those of urban planning, the social sciences, and policy. We are also mobilizing SA+P’s design capacities to unleash the creative potentials of quantitative intelligence through urban science and other collaborations with Engineering and the other schools at MIT.”

The urban science major proposes a comprehensive pedagogy, adding new material and integrated coursework. A centerpiece of this integration will be the degree’s “urban science synthesis lab” requirement, where high-tech tools will be brought together to solve real-world problems.

“This degree program will broaden our students’ perspectives and deepen their exposure in new and exciting directions,” says Anantha P. Chandrakasan, dean of the School of Engineering. “Just like the 6-14 program that EECS and Economics launched last year, this new course of study will empower and challenge students and researchers to think in new ways and form new connections. The value and relevance of computational thinking just keeps growing.”

The new major became available to all undergraduates starting in the 2018-2019 academic year. 

“The rise of autonomous vehicles, sensor-enabled self-management of natural resources, cybersecurity for critical infrastructure, biometric identity, the sharing or gig economy, and continuous public engagement opportunities through social networks and data and visualization are a few of the elements that are converging to shape our places of living. In recognition of this convergence, the MIT faculty has approved a new undergraduate degree, the bachelor of science in urban science and planning with computer science (Course 11-6).”



JOINT MAJOR PREPARES STUDENTS TO DESIGN THE VIRTUAL MARKETPLACES OF TOMORROW

A new major combining computer science and economics flourishes in its first year.

By Kathryn O'Neill | EECS Contributor

Photo: Alison F. Takemura | School of Engineering

David Autor (left), the Ford Professor of Economics and former associate head of the Department of Economics, discusses the new 6-14 major with Asu Ozdaglar, the School of Engineering Distinguished Professor of Engineering and EECS department head.

The new joint major 6-14: Computer Science, Economics, and Data Science has gotten off to a very strong start, with three newly minted graduates and 67 students enrolled in the program in the fall of 2018.

“It’s really hitting a sweet spot,” says David Autor, the Ford Professor of Economics and associate head of the Department of Economics. “I think people perceive it as being the right combination of things. [Computer science] provides really great tools, but then economics provides really interesting problems.”

Launched in the fall of 2017 by EECS and the Department of Economics, the major is designed to meet the increasing need

for graduates with the skills to apply machine learning, data analysis, and other computer science skills to the complex economic problems that have emerged from e-commerce, online social networks, and other aspects of the digital economy.

“From an MIT point of view, both departments are world-class, so bringing them together created a very appealing major,” says EECS Professor Constantinos Daskalakis, a faculty lead for the major.

“The skills are applicable to all kinds of internet companies,” Autor says. For example, all the applications of the sharing economy — from Uber to Airbnb to online dating — depend

upon bringing algorithms and market design tools together to facilitate market exchanges.

In addition, graduates of 6-14 could design algorithms for school choice programs, manage data-heavy government spectrum auctions, or even optimize the system for allocating donor kidneys. “This is a hugely important problem because there are many more people needing kidneys than kidneys available,” Autor said.

“Left and right, you see applications and companies where you put together economics and computer science to make the marketplace more efficient,” Daskalakis says. “To match efficiently requires an algorithm but also the right incentive. So that’s why the program is so popular; it’s because the topic is so timely.”

MIT students agree. In a poll of the introductory economics course 14.01, which all students are required to take, faculty found that a whopping three-quarters were interested in the joint major.

Asu Ozdaglar, School of Engineering Distinguished Professor of Engineering and EECS department head, believes that’s because combining the two disciplines requires asking complex human questions and creating complex technical models to answer them. “If you’re thinking about humans making decisions in large-scale systems, you have to think about incentives,” Ozdaglar, who is also the former director of the Laboratory for Information and Decision Systems (LIDS), said when the program was launched. “How, for example, do you design rewards and costs so that people behave the way you desire?”

To prepare students to address such challenges, 6-14 combines coursework in algorithms, statistics, probability, data science, and microeconomics.

“The goal is to master algorithms and optimization and machine learning, econometrics and statistics, as well as microeconomic theory,” Daskalakis says. “Microeconomics gives you the perspective to understand markets. You can use optimization and algorithms to optimize aspects of the design. Then, you can use machine learning and statistics to collect and analyze data that will help you optimize market design.”

This combination of tools and approaches is precisely what appealed to Marla Odell, a senior who declared 6-14 in the summer of 2017. “I was really interested in using technology as a tool to solve social and economic problems,” she said. “For me, (6-14) was a wonderful fit.”

Odell’s interest in applying computer science to economic systems was piqued by a freshman project on blockchain technology, which she did through the Undergraduate Research Opportunities Program (UROP). She said that if 6-14 did not exist, she might have double-majored in Computer Science and Engineering (6-3) and Mathematical Economics (14-2).

Course 6-14 offered her more flexibility. “This lets me take the parts I’m interested in from both sides — the analytical tools of computer science and, on the economics side, microeconomics

and game theory incentives. Those are things I’m really excited about,” Odell says.

Caroline Mak ’18, one of the first three graduates of 6-14, says she chose the combined major because she felt it would provide her with more career opportunities than economics alone. “There are all these places where you have current issues that need both of these backgrounds,” she said, noting that while she does not yet have a job lined up, she is interested in working on social issues, perhaps using data visualization. “If I was just econ, I feel it would be a harder sell — even if I took the same classes.”

Mak notes that by the time she declared 6-14 in the fall of 2017, she had already taken several of the required EECS subjects. However, she still had to take two “big, scary classes” her senior year to complete the major: 6.045[J] (Design and Analysis of Algorithms) and 6.036 (Introduction to Machine Learning).

The work was tough, but Mak says she learned a lot and really enjoyed machine learning in particular. “It covers a lot of content. I feel I understand Spotify and Amazon a lot better. I feel it demystifies some of that recommendation stuff,” she says.

Machine learning is a perfect example of the synergy between the fields of computer science and economics, according to Autor. While the field emerged from computer science, machine learning is helping economists to model human behavior and make predictions — such as about who might benefit from a drug intervention or from extra tutoring, or about how people will react to a new product offering.

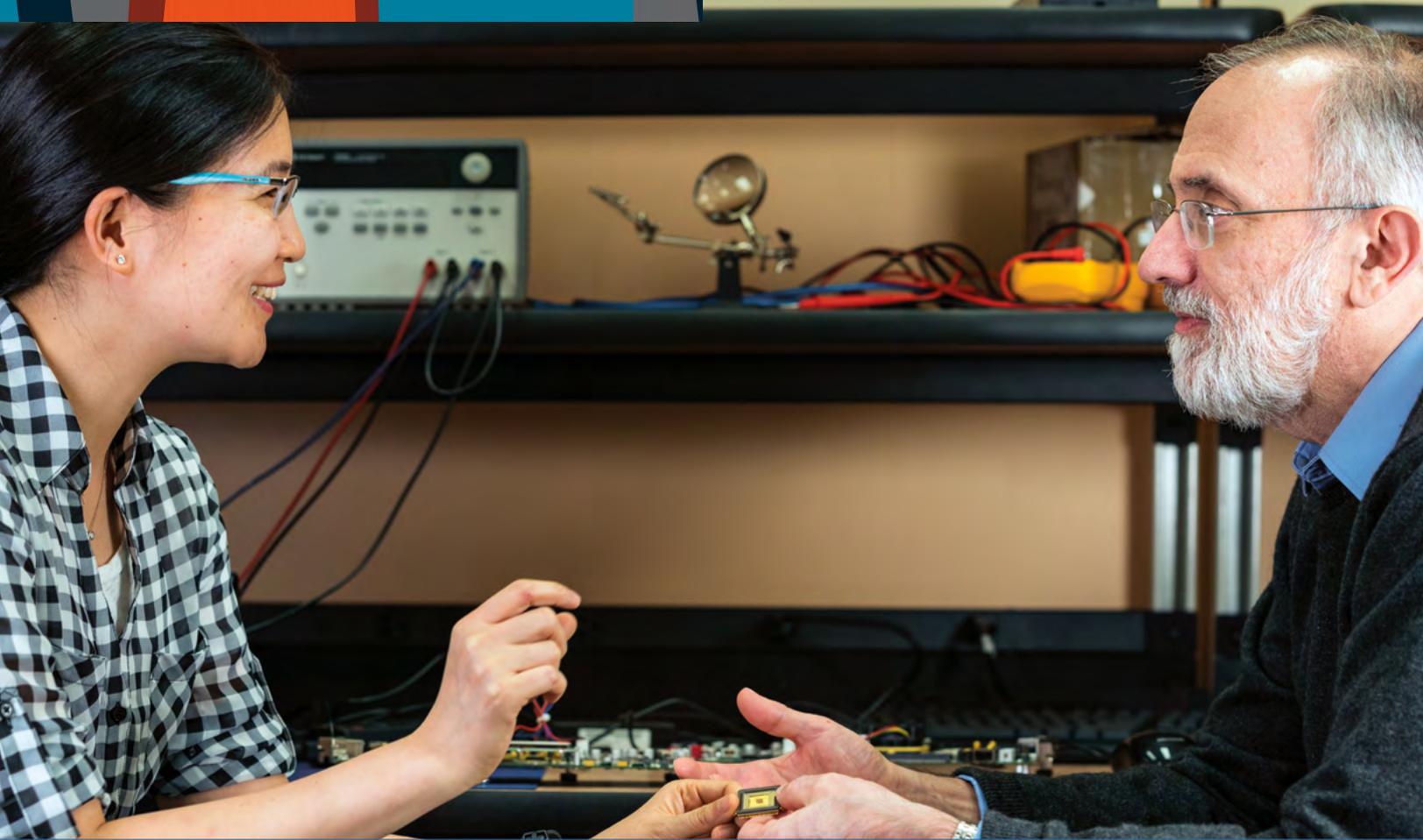
Other classes required for 6-14 range from 6.042[J] (Mathematics for Computer Science) to 14.32 (Econometric Data Science) and 14.01 (Principles of Microeconomics).

However, only one subject for the major — 6.207[J] (Networks) — an elective that utilizes random graph models, optimization, and game theory to analyze social, economic, financial, and biological networks — was taught jointly by the two departments last year. Both Autor and Daskalakis say they expect that to change in the years ahead as the collaboration between the two departments expands.

“I hope as it goes forward there will be more classes built around integrating these disciplines directly and that we will learn as the program grows what works best and how to meet the needs of students,” Autor says. “It’s going to be a learning experience for all of us.”

Daskalakis agrees. “Several classes in each department are oriented toward the other department, so what I’m expecting next is more joint course development. I also expect to see UROPs and research from undergraduates that spans the two departments,” he says. “I’m expecting the creativity of students exposed to both departments to conceive interesting projects.”

Students seeking more information about Course 6-14 should contact Anne Hunter in EECS and Eva Economou in the Department of Economics for more information. 



BUILDING THE HARDWARE FOR THE NEXT GENERATION OF ARTIFICIAL INTELLIGENCE

A class taught by Vivienne Sze and Joel Emer brings together traditionally separate disciplines for advances in deep learning.

By Meg Murphy | School of Engineering

Photo: Lillie Paquette, School of Engineering

Vivienne Sze and Joel Emer

On a recent Monday morning, Vivienne Sze, an associate professor of electrical engineering and computer science at MIT, spoke with enthusiasm about network architecture design. Her students nodded slowly, as if on the verge of comprehension. When the material clicked, the nods grew in speed and confidence. “Everything crystal clear?” she asked with a brief pause and a return nod before diving back in.

This new course, 6.S082/6.888 (Hardware Architecture for Deep Learning) is modest in size — capped at 25 for its first run — compared to the bursting lecture halls characteristic of

other MIT classes focused on machine learning and artificial intelligence (AI). But this course is a little different. With a long list of prerequisites and a heavy base of assumed knowledge, students are jumping into deep water quickly. They blaze through algorithmic design in a few weeks, cover the terrain of computer hardware design in a similar period, then get down to the real work: how to think about making these two fields work together.

The goal of the class is to teach students the interplay between two traditionally separate disciplines, Sze says. “How can you

write algorithms that map well onto hardware so they can run faster? And how can you design hardware to better support the algorithm?" she asks rhetorically. "It's one thing to design algorithms, but to deploy them in the real world you have to consider speed and energy consumption."

"We are beginning to see tremendous student interest in the hardware side of deep learning," says Joel Emer, who co-teaches the course with Sze. A professor of the practice in EECS as well as a senior distinguished research scientist at the chip manufacturer Nvidia, Emer has partnered with Sze before. Together, they wrote an IEEE journal article that provides a comprehensive tutorial and survey coverage of recent advances toward enabling efficient processing of deep neural networks. It is used as the main reference for the course.

In 2016, their group unveiled a new, energy-efficient computer chip optimized for neural networks, which could enable powerful AI systems to run locally on mobile devices. The groundbreaking chip, called "Eyeriss," could also help usher in the Internet of Things.

"I've been in this field for more than four decades. I've never seen an area with so much excitement and promise in all that time," Emer says. "The opportunity to have an original impact through building important and specialized architecture is larger than anything I've seen before."

Hardware at the heart of deep learning

Deep learning is a new name for an approach to AI called neural networks, a means of doing machine learning in which a computer learns to perform some tasks by analyzing training examples. Today, popular applications of deep learning are everywhere, Emer says. The technique drives image recognition, self-driving cars, medical image analysis, surveillance and transportation systems, and language translation, for instance.

The value of the hardware at the heart of deep learning is often overlooked, says Emer. Practical and efficient neural networks, which computer scientists have researched off and on for 60 years, were infeasible without hardware to support deep learning algorithms. "Many AI accomplishments were made possible because of advances in hardware," he says. "Hardware is the foundation of everything you can do in software."

Deep learning techniques are evolving very rapidly, Emer says. "There is a direct need for this sort of hardware. Some of the students coming out of the class might be able to contribute to that hardware revolution."

Meanwhile, traditional software companies like Google and Microsoft are taking notice and investing in more custom hardware to speed up the processing for deep learning, according to Sze.

"People are recognizing the importance of having efficient hardware to support deep learning," she says. "And specialized hardware to drive the research forward. One of the greatest limitations of progress in deep learning is the amount of computation available."

"Students in Hardware Architecture for Deep Learning are jumping into deep water quickly. They blaze through algorithmic design in a few weeks, cover the terrain of computer hardware design in a similar period, then get down to the real work: how to think about making these two fields work together."

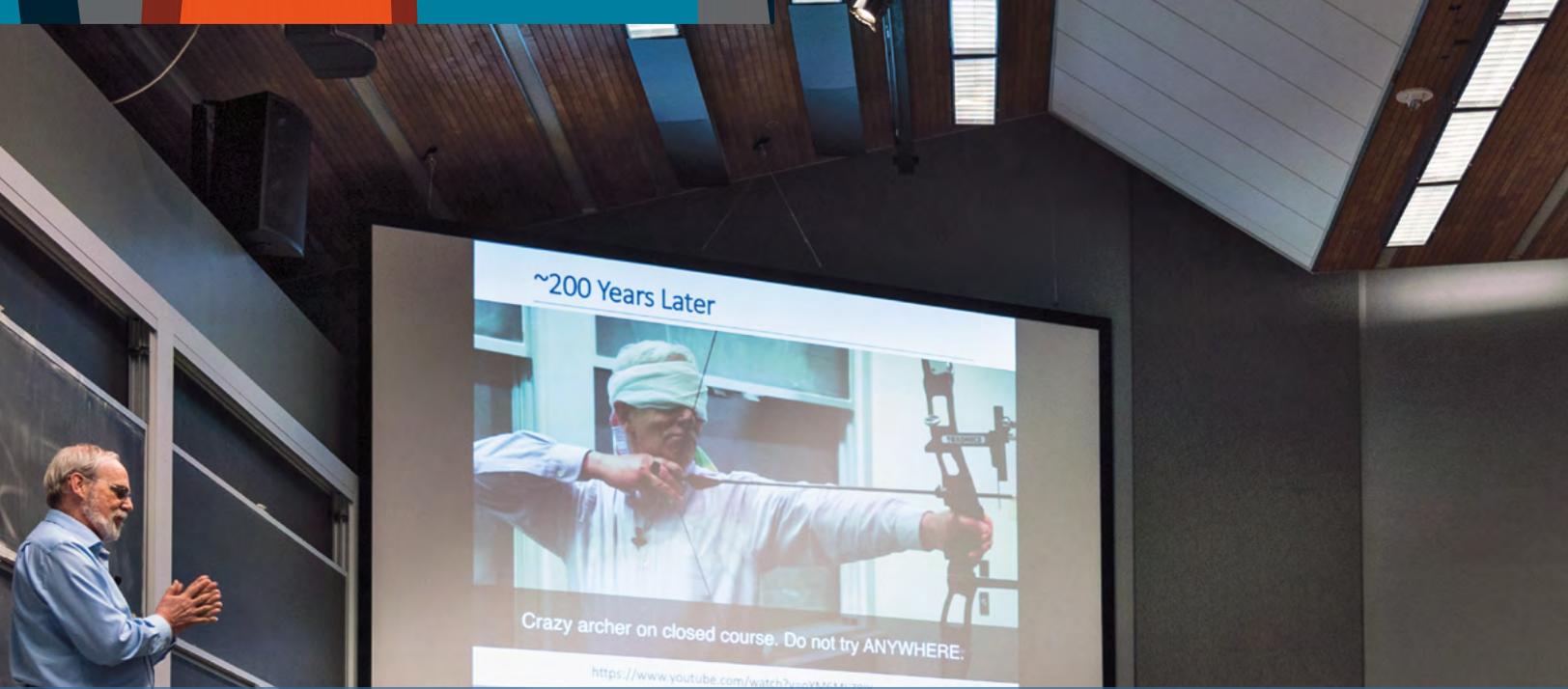
New hardware architectures

Real-world deployment is key for Skanda Koppula, a graduate student in EECS. He is a member of the MIT Formula SAE Race Car Electronics Team.

"We plan to apply some of these ideas in building the perception systems for a driverless Formula student race car," he says. "And in the longer term, I see myself working toward a doctorate in related fields."

Valerie Sarge, also a graduate student in EECS, is taking the course in preparation for a career that involves creating hardware for machine learning applications.

"Deep learning is a quickly growing field, and better hardware architectures have the potential to make a big impact on researchers' ability to effectively train networks," she says. "Through this class, I'm gaining some of the skills I need to contribute to designing these architectures." 



COMPUTATION COUNTS: PYTHON-BASED COURSE SEES ENORMOUS GROWTH

Students are flocking to 6.00 (Introduction to Computer Science and Programming Using Python), where they learn not just coding, but computational thinking as well.

By Meg Murphy | School of Engineering

Photo: Lillie Paquette, School of Engineering

In a 6.00 class, Chancellor for Academic Advancement Eric Grimson illustrates the concept of random sampling with a video featuring MIT Professor John Guttag, the originator of 6.00, as a blindfolded archer.

When James Quigley applied to MIT, he didn't need an algorithm to tell him getting in wasn't a high-probability outcome. An Army veteran attending community college in California, he possessed a talent for math, a desire to do big things, and a sobering group of friends who insisted: "Mortals don't get into MIT." Quigley knew a dare when he heard one. As for probability measures, those he chose to ignore.

Now a second-year student at the Institute, Quigley was recently sitting in a lecture for 6.00 (Introduction to Computer Science and Programming Using Python). The topic of the day was using a computer simulation to estimate the value of an unknown quantity: the probability of winning at solitaire. He's taking the class to learn to think like a computer scientist, he says. He speaks of Python, his first real computer programming language, with awe.

"When I first started Python, I basically felt like I was learning some unfathomable witchcraft. Many of the concepts still feel hard to grasp, and that feeling is what made me love it," says Quigley. "People can use 1s and 0s to cure diseases, unite people, or destroy nations. Who wouldn't be fascinated by something like that?"

It has been around since 2005, but over the last few semesters, 6.00, like the Course 6 major itself, has seen enormous growth in enrollment, with 424 students from 10 departments enrolled in 6.0001 this spring. (6.00 was recently split into two half-term subjects, 6.0001 and 6.0002.) About 60 percent are first- or second-year students, according to the class roster, with the remainder a mix of juniors, seniors, and graduate students. In spring 2016, 239 students enrolled, followed by 425 that fall. By the fall of 2017, it rose to 507. "It's 2018, and even children are learning to code," Quigley says.

"We teach computational thinking. It involves far more than coding. We start out with programming, which involves the creative application of math and critical thinking," says Ana Bell, a lecturer in the Department of Electrical Engineering and Computer Science. She delivers the majority of the lectures in 6.0001. "Programming requires you think about math in a deeply logical manner while following the rules of language and being creative in your constructs," she says. "With programming at the base, you can use computations and simulations to model and attempt to explain almost everything around us. That's computer science."

"Even if you never again write a program in your life," says Quigley, "coding forces you to account for every possibility. It also teaches you that being wrong doesn't mean you don't progress. When I code, I'm wrong over and over until finally I'm right," he adds.

A computing mindset

In one of MIT's largest lecture halls, Quigley listens intently as computer scientist Eric Grimson, chancellor for academic advancement, describes Monte Carlo simulation, a method of estimating the value of an unknown quantity using principles of inferential statistics. In rapid succession, Grimson describes using randomized computation to solve problems that are not inherently random; employs coin flips and roulette wheels to explore quantifying variation in data; and illustrates the concept of random sampling with a staged video featuring MIT Professor John Guttag, the originator of 6.00, as a blindfolded archer.

Bell, who is sitting in the front row, smiles as she watches the video with the class. On screen, she helps Guttag simulate a computer programming method via a campy scene that involves fleeing students and arrows piercing books and furniture. It is all part of the fun for Bell, who has loved programming since building a computer at age 11. She also co-teaches 6.0002 (Introduction to Computational Thinking and Data Science), an additional class offered on the heels of the introductory course. The majority of 6.0001 students, such as Quigley, remain for the advanced section.

Bell enjoys guiding novices through the sometimes intimidating realm of computer science. She remembers how difficult it was, at first, to switch her own way of thinking and grasp tough concepts, such as object-oriented programming. "Sometimes students come to my office and they just don't get it — but I know they can get it." So, she'll take a multipronged approach: draw something on the chalkboard, write the code, run the code with test cases, explain it in words. "Sometimes it takes them a really long time — but the switch occurs. They switch to a computational way of thinking; the students become the computer."

First-year student Darya Guettler says the material resonates with most students because analyzing data is a core element in all engineering and science disciplines. "I have also found that I am able to look at seemingly random processes in the world as quantifiable now, so this class has given me a new perspective through which to view the world," she says.

The appeal of mastering such thinking is clear to Michael Gritzbach, a visiting undergraduate student at Harvard University. His current focus is Chinese foreign policy and intensive Russian, but he nevertheless enrolled in 6.0001/2 at MIT. "Computer science is becoming more important for all aspects of our lives — in apps, games, or social media algorithms that influence society and politics," says Gritzbach, who studies management, philosophy, and economics in Frankfurt.

According to Guttag, who has helped shepherd 6.00/6.0001/6.0002 from the beginning, 6.0001/2 is often difficult for students from non-computer science disciplines, but in a good way. "For a lot of students, it's a struggle because it's a very different way of thinking," he says. "But at the end of the day, they're glad they learned the material. And they see that computer science isn't all about learning to build operating systems or compilers, or about designing clever data structures. This field is really about learning to use computation to do things that matter."

People with no prior exposure to computer science or programming can also learn to think computationally by signing up for the two-course sequence for free on MITx, MIT's collection of massive, open, online courses (MOOCs) "We put a bunch of the course material on MITx so students have the ability to watch the videos and learn at their own pace," says Bell. "It's awesome to see the class being taught to the world."

Quigley, like his classmates, recognizes the potential. "I want to do more than just coding; I want to build things," he says, describing why he chose to major in EECS. "I've heard it said that computer engineering is taking lightning, putting it in a box, and tricking it to think. Sounds like fun to me." 🌩️



Second-year student James Quigley, pictured here with EECS Extraordinary Lecturer Ana Bell, finds the Python computer language challenging yet fascinating.



NEW AND IMPROVED EECS CLASSES: A ROUNDUP

EECS has been busy launching, updating, and revamping the department's introductory electrical engineering offerings.

By EECS Staff and Faculty Contributors

Photo: EECS Staff

Lara Shonkwiler, a sophomore in EECS, prototypes a circuit in a revised 6.002 [Circuits and Electronics] course.

As part of its ongoing efforts to improve its undergraduate curriculum, EECS has made significant revisions to several introductory subjects in electrical engineering.

These changes, recommended by the department's Committee on the Future of Electrical Engineering, are intended to provide better integrated, more engaging introductions to key concepts and demonstrate their value in solving contemporary problems. Revised and new classes include:

6.002 (Circuits and Electronics)

In fall 2017, EECS undertook the first major revision of 6.002 in about 20 years. The goal: rethinking content and delivery. Faculty refocused the class on processing signals and energy, with more emphasis on linear devices and less on circuitry for computation as the prime motivator.

In addition, they added a weekly lab component that includes authentic examples building on course content, culminating in a multi-week lab that used the Doppler effect to infer velocity from ultrasound waves. They also moved the homework to the CAT-SOOP learning-management system, which automatically collects and assesses online exercising, allowing for instant feedback and removing the need for manual grading.

6.003 (Signals and Systems)

This course was originally designed more than 40 years ago as the launching point for the study of signals and systems, an area of continuing interest in virtually every engineering field and in physics as well. Over the years, new content has been added to 6.003, most significantly in the area of discrete-time signals and systems, which are increasingly important as digital electronic systems have become widely available.

To better communicate both the technical content and its utility, faculty have refactored the content in 6.003 and its follow-on subjects so that signal-processing theory (which has always been a part of 6.003) and its applications (which had traditionally been reserved for higher-level subjects) are combined in one subject (6.003). Meanwhile, the feedback and control component and its applications have been combined in another subject (6.302).

Students in the first edition of the new 6.003 were enthusiastic about new lab exercises building on signal-processing concepts retained from the older 6.003. Faculty are now streamlining hands-on activities and strengthening connections between theoretical ideas and practical applications.

6.004 (Computational Structures)

The EECS introductory subject on digital design and computer architecture has also undergone substantial revision. This foundational subject, needed for all subsequent systems subjects in EECS, enrolls more than 500 students annually. The biggest change: making the subject much more hands-on through the use of modern hardware-design tools, specifically the Bluespec language.

Bluespec's design is informed by the latest developments in the programming languages, and embodies a novel approach to concurrency issues in hardware design. Starting from basic combinational and sequential circuits, students end up building several versions of pipelined RISC-V processors and its associated memory system from scratch.

6.S077 (Introduction to Data Science)

Launched in spring 2018, this new course introduces basic statistical concepts through a rich collection of applications and hands-on experience with real data. It's intended to provide a solid conceptual foundation to the field of data-driven modeling, prediction, and inference.

The course introduces students to mature and informed approaches, including discussions of the main and common statistical pitfalls that modern-day data scientists should understand. Rather than covering a long list of popular statistical methods and algorithms, the course highlights the key conceptual ingredients of sound methods, developed in the context of select applications — drawn from electrical engineering, computer science, social science, and the life sciences — that will serve for both motivation and practice.

6.012 (Microelectronic Devices and Circuits)

This course has been completely revamped with lectures, recitations, problem sets, tests, a new final project, and optional labs.

Class content emphasizes cross-layer interactions. Students start by examining key metrics of a realistic computing system and derive how low-level device physics are critical for determining the specifications of such systems. This motivates the majority of the coursework, which focuses on understanding device physics.

A new final project challenges students to modify a starting transistor to realize the most energy-efficient commercial processor core. This project uses industry-standard CAD tools and connects device design all the way up through system performance.

The class includes a lab in which students can fabricate their own transistors and small logic gates, giving them unique hands-on experience with nanofabrication. Although the lab is optional, most students choose to participate.

The course also delves into advanced state-of-the-art devices and technologies, tracing the remarkable progression of semiconductor technology over the decades. 



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DOING IT ALL – AND THEN SOME

EECS alumna Yonina Eldar is a powerful force in signal processing research — and in the classroom and at home as well.

By Kathryn O'Neill | EECS Contributor

A leading light in the cutting-edge field of signal processing, Yonina Eldar PhD '02 is pioneering ever-more-efficient ways to process wideband signal data — work that promises to revolutionize applications as diverse as wireless communications and ultrasound imaging.

Currently a professor of electrical engineering at Technion-Israel Institute of Technology, Eldar is the author or co-author of four books, including “Sampling Theory: Beyond Bandlimited Systems” (Cambridge University Press, 2015), and has well over 200 published papers, numerous awards, and a dozen patents to her name.

How does she do it all?

Alan V. Oppenheim, Ford Professor of Engineering at MIT, jokes that she doesn't. “One person could not possibly be that productive,” he says. “There have to be five of them, and they're all very clever about not showing up at the same place at one time.”

But Eldar does seem to do it all, and then some. In addition to her groundbreaking work in signal processing, she is also the mother of five children who are 3 to 20 years old. And she's the co-founder (with her husband) of Inbar, a nonprofit organization dedicated to “creating opportunities, providing tools, and supporting all aspects of love and relationship for people with disabilities.”

“The thing about Yonina is that when she decides to do something, there's nothing that gets in the way of that getting done,” says Oppenheim.

Quantum signal processing

Eldar came to MIT from Israel in 1998 in a move that might have seemed daunting to some. She had an 8-week-old infant and a husband who didn't speak English, and she had just signed up to do her PhD in signal processing. “I believe in instincts and opportunities,” she says.



Yonina Eldar, professor of electrical engineering at Technion-Israel Institute of Technology. Photo: Avishag Shaar-Yashuv

Eldar was drawn to MIT by the opportunity to work with Oppenheim, who wrote “Digital Signal Processing” (Prentice Hall, 1975), the textbook she used as an undergraduate at Tel Aviv University.

Oppenheim says that Eldar's acceptance to MIT was no guarantee he would take her on as an advisee, but she ultimately met his four criteria for PhD students: “They have to be intelligent; they have to be creative, out-of-the-box thinkers; and they have to be fun to have a beer with. And the fourth is coachable,” he says. “Yonina is off the scale in all of those dimensions.”

Eldar is equally complimentary of Oppenheim. “Al is one of the most creative people that I know,” she says. “MIT, and especially Al Oppenheim, had a huge impact not just on my career, but on my thinking as a researcher and a person. Al is a phenomenal and dedicated mentor and teacher who really takes the time with his students not only to discuss results but also to educate them.”

Oppenheim likes to explore unconventional ideas, and it is he who suggested Eldar research quantum signal processing for her dissertation. “What is that?” Eldar says she asked him at the time. “He said, ‘I don’t know. You have four years to figure it out.’”

Eldar ended up borrowing concepts from quantum mechanics to identify new ways to recover useful information from corrupted signals. Since that time, she has continued to push signal processing forward as a faculty member at Technion, where she runs the Signal Acquisition Modeling and Processing Lab.

Sub-Nyquist sampling

Signal processing is critically important in today’s digital world. Creating faithful digital reproductions of anything from a violin concerto to a photograph requires taking enough samples from the original that gaps are not noticeable — while eliminating enough data to ensure speedy transmission. This is the essence of signal sampling, and according to a mathematical principle known as the Nyquist Theorem, a minimum number of samples must be taken to ensure the signal is reproduced clearly.

One of Eldar’s key contributions to signal processing has been to show that there are ways to produce faithful signals with sub-Nyquist sampling. She developed Xampling, a system architecture that can sample and process analog inputs at far below the Nyquist rate. She even built hardware to show the practicality of her theory.

“She has made a big push of taking ideas and using them to create practical, implementable systems,” says Thomas A. Baran PhD ’12, co-founder and CEO of Lumii and a research affiliate (with Eldar) in the Digital Signal Processing Group in MIT’s Research Laboratory of Electronics. “This is remarkable, especially given that her publications tend to be more theoretical.”

Eldar says she began building hardware after discussing her sub-Nyquist sampling theory with engineers. “They said, ‘We’re not arguing with the theory, but it won’t work in practice,’” she says. Piqued, Eldar hired an engineer to build a prototype.

“After we built the first prototype, I really got excited about this path,” she says, noting that the prototype worked but revealed weaknesses in her initial design. “Once you understand the engineering challenges, it changes how you think about theory.”

Practical applications matter to Eldar because she wants her work to be useful in the world. To that end, her lab has applied sub-Nyquist sampling to develop a small, portable ultrasound

system that promises to make that diagnostic tool more widely accessible. She is also investigating ways to improve the resolution of microscope imaging.

Teaching and volunteering

Of course, Eldar is not only a researcher but a professor. “She is a brilliant teacher,” Oppenheim says. “She understands the material so deeply she can convey it with tremendous insight and energy.”

She teaches three subjects a year and typically has about eight graduate students, a few postdocs, and several undergraduates working in her lab. “I’m extremely passionate about involving undergraduates in our activities,” she says.

These activities include volunteering together on projects ranging from visiting the elderly to painting a facility for handicapped children. Which once again raises the question: How does she do so much?

Eldar credits her productivity to setting priorities and keeping a detailed schedule. “There are always a million things that demand your time. So, what are the things that are important to me?” she says. “Family, research, mentoring, teaching, being part of society, volunteering, and academic service.”

Eldar says focusing on priorities means she can’t really do everything. For example, she limits the number of trips per year. “That’s a very hard rule to follow,” she says. “But I can’t be a mother, do good research, and be on a plane every three weeks.”

Maybe not, but those who know Eldar say she stands out for what she does do — maintaining an “incredibly aggressive publishing schedule” while tackling “high-risk ideas,” as Baran notes.

“Everyone in the Signal Processing Group family, they are all kind of in awe of her,” he says. She is a force. 🦹

“The thing about Yonina is that when she decides to do something, there’s nothing that gets in the way of getting that done. She’s a woman with tremendous energy.”

—Alan V. Oppenheim, Ford Professor of Engineering



BRIDGING THE DIGITAL DIVIDE

EECS alumni Godfrey Tan and Allen Miu launched Frontiir to help bring Myanmar into the internet age.

By Eric Smalley | EECS Contributor

A couple of entrepreneurs setting up shop in a new city is a familiar story among EECS grads. Godfrey Tan, also known as Wai Lin Tun, and Allen Miu, both SM '02 and PhD '06, have a decidedly less-common variation on that theme.

The two, along with partner Minn Thein, launched a high-tech company in Myanmar, a Southeast Asian country still emerging from the shadow of a long-lived military dictatorship. In less than six years, their business, internet service provider (ISP) Frontiir, has grown to more than 1,500 employees, gone a long way toward bridging the country's massive "digital divide," and fostered a culture of innovation, team spirit, and accountability — and most important, the right way of doing business that's free of corruption and cronyism.

Myanmar's transition to democracy, ongoing over the last decade, has opened the country to investment and business development, but decades of isolation have left the country with many challenges. Frontiir took on the task of building a network and business to provide both enterprise and consumer internet access in a country with very little telecommunications infrastructure, low median income, a population unfamiliar with the basics of internet access, and a government struggling to curb corruption and develop coherent licensing practices.

With a population of 54 million — larger than the populations of Canada, South Korea, or Spain — Myanmar is also a land of opportunity for consumer-tech companies. So Tan, now Frontiir's chairman and CEO, left a position at Intel and returned to Myanmar, where he knew he could use his skills in wireless networking to help bring the population into the internet age. When Tan invited his classmate to join him, Miu jumped at the chance. Miu, now Frontiir's chief technology officer, had been working at an international wireless networking company that helped bring affordable internet access to several Indian cities, which was precisely the experience Frontiir needed. For Miu, it was a chance to step out from layers of product management and sales to be on the ground with a startup serving a unique market.

Tan recognized that the first step in establishing Frontiir was gaining credibility with the government. To that end, the two donated a wireless network to a local university. That put them on the government's radar, and when Myanmar hosted the Southeast Asian Games in 2013, the government turned to Frontiir to build critical networks in time for the games. Frontiir built a security system with barcode scanning for venue access and networked the venues across four cities via an overlay network so game scores could be posted in real time.

When they launched the company in January 2013, less than 2 percent of households in Myanmar were wired for telecommunications. Building a wireless network was the obvious way to go, but that raised a big question: How do you build, from scratch, a network with tens of thousands of access points serving hundreds of thousands of people — and simultaneously provide affordable internet access in a developing country?

For Frontiir, the answer was do-it-yourself vertical integration. The company developed a massively scalable Wi-Fi network using software-defined networking — meaning that, rather than purchasing specialized networking hardware, the company bought inexpensive generic Linux boxes and loaded them with the company's own software.

Among the toughest challenges they faced was finding reliable electricity. Frontiir built a proprietary technology that pushes the routing of data traffic to the edge of the network, literally inside a small outdoor cabinet, and significantly reduces the number of fiber connections needed while providing Wi-Fi accessibility right inside the home without extra equipment. The company's capital expenditure is 10 to 20 times lower than the cost of building cellular networks or fiber-to-the-home (FTTH) networks, Miu says. In addition, the scalable network technology allows the company to generate cash flow even with a very small subscriber base within a specific area and upgrade the network capacity with more fiber nodes and even offer FTTH service as the subscriber base and traffic demand increase.

Subscribers pay about 15 cents per day using the same type of scratch-off, top-up cards they're familiar with from purchasing cellular phone service. Frontiir is the largest ISP in Myanmar with more than 500,000 customers, Tan says. The company is the country's third-largest data carrier by volume, and is close to taking over second place, Miu adds. They expect to become the largest data carrier in Myanmar in a year or so.

Frontiir faces cultural challenges as well as technological and economic ones. More than 90 percent of the company's employees are Myanmar-born but have never been outside of the country, and the founders have had to teach employees about the importance of customer orientation and accountability — concepts that, until recently, weren't emphasized in Myanmar, Miu says. Myanmar also continues to struggle with human rights and political stability. "We're hopeful," Miu says of those issues. "The last thing you want to do is shy away from them. You really want to be in the action and keep pushing what you think is right."

Tan aims for the company to help shape the future of Myanmar by bringing affordable digital access and, with it, fostering freedom of speech, creating new jobs, and improving health and education. He plans to create more than 100,000 jobs in the next two decades, and is also

looking to export the company's technologies to other developing countries such as India and Bangladesh.

Tan and Miu followed similar paths from childhoods in Asia to MIT's EECS department, including moving to North America to escape political repression. Tan moved to California after graduating from high school in Myanmar. He worked in grocery stores while attending community college part time before transferring to the University of California at Berkeley. He was accepted to the EECS doctoral program, but initially deferred admission to work at a small tech company. But after just 20 months, Tan chose to give up his stock options and pursue his childhood dream of attending MIT, a dream sparked by promotional material about MIT he'd seen in the American Center back in Yangon, Myanmar. Miu's family moved from Hong Kong to Canada when he was 7, in anticipation of Hong Kong returning to Chinese rule.

Tan and Miu were acquainted at UC Berkeley but became close friends at EECS, where they conducted research on wireless networking. "We sat in the same office at MIT and became the best of friends," says Tan. "I knew that one day I'd want to build a company together."

Intense debates and the ad hoc presentation and defense of ideas were key facets of Tan's MIT experience, he says. Advisor John Guttag, the Dugald C. Jackson Professor of EECS, taught him how to organize complex thoughts and ideas into layers of abstract ideas that are organized and simple to process, he says. Tan also got to work closely with Miu's advisor, Fujitsu Chair Professor Hari Balakrishnan. "He taught us how to think fast, remove the unimportant quickly, and how to present your thoughts," he says. Another key skill he learned and got to practice at MIT was formulating problems. "Once the problem is well defined, the solution paths become clearer," he says. "Many smart people can solve specific issues, but few can define the problems well."

That's experience that's clearly contributed to Frontiir's success. 

"Building a wireless network was the obvious way to go, but that raised a big question: How do you build, from scratch, a network with tens of thousands of access points serving hundreds of thousands of people — and simultaneously provide affordable internet access in a developing country?"

FROM STAR WARS TO SIGGRAPH

Jonathan Ragan-Kelley channeled a childhood passion for visual effects into groundbreaking work on high-efficiency computer graphics.

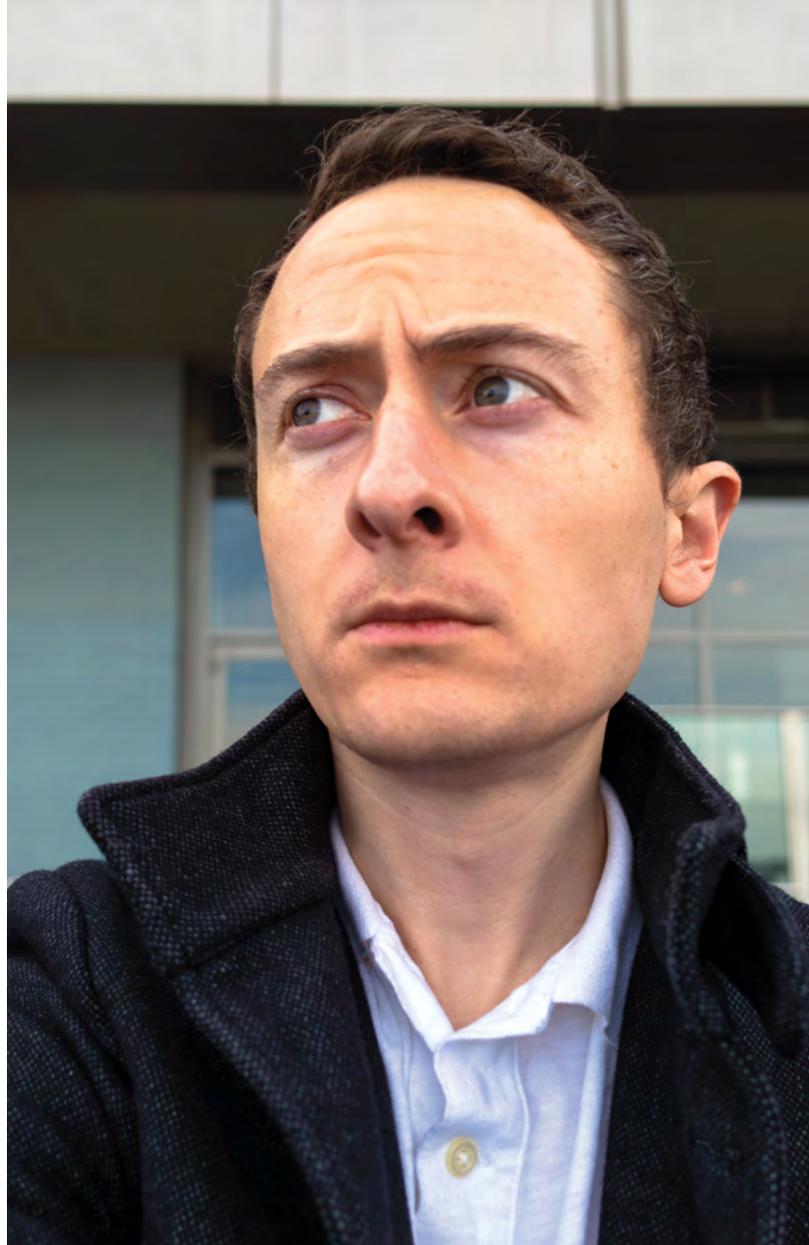
By Catherine O'Neill Grace | EECS Contributor

When Jonathan Ragan-Kelley SM '07 PhD '14 saw his first "Star Wars" movie as a boy, it didn't inspire him to be a Jedi warrior. But it did awaken a lifelong passion for visual effects.

"'Star Wars' was the first thing I got hooked on as a young kid," he says. "I was most interested in the computer-graphics technology and in visual effects. I'm dating myself somewhat — although it speaks to how early this started for me — because when I was first learning about it, it was largely not done with computers."

Instead, he says, "all the space battles were done with robotics: motion-controlled cameras and little miniature models. So instead of a spaceship flying, they would have a model of a spaceship sitting in one place and they would move the camera, so that the relative movement of the two things was as if the ship were flying."

These days, Ragan-Kelley is assistant professor in the Department of Electrical Engineering and Computer Science at the University of California at Berkeley. He's a primary faculty member in Berkeley's Computer Graphics Group, which studies scientific visualization, physically based rendering, animation, and computer-aided geometric design, among other things. And he's on the team for the university's new ADEPT lab, which seeks "to dramatically improve computing capability by reducing the cost and risk of designing custom silicon for new application areas."



[Professor Jonathan Ragan-Kelley](#)

Ragan-Kelley's work centers on high-efficiency computer graphics. In his bio on the Berkeley website, he says he's actively seeking PhD candidates to work with him on applying systems, compilers, programming languages, and specialized architectures to graphics, vision, deep learning, and computational photography problems.

Working with EECS professors Frédo Durand and Saman Amarasinghe at MIT's Computer Science and Artificial Intelligence Lab (CSAIL), Ragan-Kelley helped develop the image-processing language Halide. (In a nod to photography's past, the language is named for the chemical compound used to fix light on paper.) In Halide, the developers found ways to dramatically decrease the amount of code needed for image-processing operations.

"We worked at the intersection of machine learning and programming languages," Durand notes. "Jonathan sees solutions that are intellectually deep, but practical. He teaches people to look at problems differently. Often, his

contribution is in seeing a lot of use in the real world. He is probably the best I have ever worked with at seeing the big picture.”

Halide resides very much in the real world. The language has been widely adopted by engineers at Google and elsewhere. Google Photos, high-dynamic range (HDR) pictures taken with Android phones, and videos uploaded to YouTube are all processed with Halide code.

“Halide’s used in niches in a bunch of different places,” Ragan-Kelley says. “Relative to something like Java or Python, it’s minuscule, but it’s a really useful and powerful tool for certain types of problems. In those contexts, it’s been able to have very high impact, because those are settings where a couple of people write really important code that’s used every day by a billion people.”

The first large piece of commercial Halide code that was deployed was on the HDR Plus pipeline from Google, he says: “It’s an algorithm that makes high-quality individual images by taking bursts of lower-quality images and combining them together intelligently.”

In August 2018, Ragan-Kelley and colleagues — including Durand, his MIT thesis advisor — presented a technical paper, “Differentiable Programming for Processing and Deep Learning in Halide,” at the 45th annual meeting of the Association for Computing Machinery’s special interest group on Computer Graphics and Interactive Techniques (better known as SIGGRAPH).

It was far from Ragan-Kelley’s first appearance there. He found out about the computer-graphics conference when he was a teenager trying to figure out the technology that ran video games such as *Myst*.

“In high school, I had seen this postage-stamp-sized Quicktime video, which you can actually see on YouTube today, called ‘The Making of *Myst*,’” he recalls. “It was a 10-minute behind-the-scenes thing, talking about how they did everything, and it kind of blew my mind. It brought all the different pieces together. Not long after that, I was working on my own, trying to figure out how to find the software that they’d used and other related things. A friend of a friend happened to be connected in that world, and let me know that it was possible to go to SIGGRAPH as a student volunteer. I started going the summer after my sophomore year in high school.”

Ragan-Kelley has been a SIGGRAPH regular ever since. “It’s where I’ve published most of my work,” he says. “It’s both a professional thing and an academic thing.”

After MIT, Ragan-Kelley worked as a postdoctoral researcher in computer science at Stanford. He then spent a year as a visiting researcher at Google, and has worked at major GPU vendors — Intel, Nvidia, and AMD — on

“Ragan-Kelley started out wanting to be a technical director for the movies. But as he moved through his undergraduate studies at Stanford and his graduate work at MIT, he realized that he was more interested in the tools than the actual filmmaking.”

architecture, compilers, and research. He also designed and built Lightspeed, a real-time preview system for the special effects industry, in collaboration with Industrial Light & Magic, the visual-effects and animation studio founded by producer-director George Lucas. That was surely a dream assignment for someone whose interest in the field started with Lucas’ “Star Wars.”

Lightspeed is a timesaving, automated approach for high-quality preview of feature-film rendering during lighting design. Ragan-Kelley, Durand, and others presented a paper introducing it at SIGGRAPH in 2007.

Ragan-Kelley started out wanting to be a technical director for the movies, “a slightly weird name for a person who does a range of different jobs in visual effects and feature animation,” he says. As his path moved through his undergraduate studies at Stanford and his graduate work at MIT, he realized that he was more interested in the tools than the actual filmmaking.

“What has kept me going is an interest in the underlying technology. Originally, the template in my mind for my career path was creating things in a visual-effects studio, not going one level more meta than that and making tools for those people,” he says.

“I do have a unifying theme for the research that I do, that I’ve always done. At some level, I’ve always been interested in building better tools for people.” Originally, the idea was building better tools for artists who were making movies, but that’s long since shifted to programming languages and compilers. “But I see that the role is largely the same,” he says. “It’s all based on understanding what the problems are in doing a certain kind of task, and how intelligent automation could give people much higher leverage.”

Follow Jonathan Ragan-Kelley on Twitter @jrk. 

A portrait of Benjamin Williams, a man with glasses and a goatee, smiling. He is wearing a blue and white plaid shirt under a dark suit jacket. The background is a whiteboard with some faint diagrams and equations.

ON THE ELECTROMAGNETIC FRONTIER

Benjamin Williams is developing new lasers that could be used for anything from helping radio telescopes look deeper into space to enabling inspectors to peer into packages without opening them.

By Catherine O'Neill Grace | EECS

[Professor Benjamin Williams](#)

Today, Benjamin Williams SM '98 PhD '03 is an associate professor of electrical and computer engineering at the University of California at Los Angeles — but he took what you might call an indirect route to get there.

"I came from a small, rural high school, and I didn't know much more than that I liked math and I liked science," Williams recalls. So he enrolled in a small liberal arts college, Haverford College in Pennsylvania, where he majored in physics. His undergraduate thesis focused on mixing in two-dimensional turbulent fluid flows — and he received the American Physical Society's Leroy Apker Award.

But Williams knew pretty quickly that theoretical physics was not for him. "I went to a string-theory lecture, and I came away saying, 'I do not want to do that. I want to do something that's more applied, where I can flip a switch at the end of the day, and if the thing works, then I'll know that I did it right. If it doesn't work, then I know I didn't.'"

Williams took a simple circuits course, enjoying it enough that it set him on the path to electrical engineering. In graduate school at MIT, Williams sought out an advisor by looking through faculty descriptions "for people who had the word 'quantum' in the bio, and then I tried to get into their labs." He ended up developing quantum cascade lasers in the group

led by Qing Hu, now Distinguished Professor of Electrical Engineering and Computer Science at MIT.

"When I joined, [the lasers] had not been made in the terahertz," Williams says. "I spent most of my PhD working with him trying to make the first terahertz quantum cascade laser — and it was not at all clear that it was going to work out."

Williams spent four years during his PhD research developing prototypes and "flicking the switch. Every three months, I'd build something new and flip the switch and it wouldn't work. It took awhile."

Developing lasers in the THz range, which occupies space on the spectrum between microwave and infrared, is "one of the last frontiers of electromagnetics," Williams says. "It's very difficult to generate radiation or light there, and it's been difficult to detect it. It's been difficult to manipulate it."

Building a laser to generate longer and longer wavelengths requires energy levels that are closer and closer together, he explains. "Prior to terahertz quantum cascade lasers, there just weren't a lot of good options to make semiconductor lasers with such closely spaced energy levels. However, the tools of nanotechnology provide a path forward."

“I went to a string-theory lecture, and I came away saying, ‘I do not want to do that. I want to do something that’s more applied, where I can flip a switch at the end of the day, and if the thing works, then I’ll know that I did it right. If it doesn’t work, then I know I didn’t.’”

—Benjamin Williams

The technique Williams and colleagues use involves engineering artificial atoms or artificial molecules — manufactured materials that share the energy levels of atoms. Others had previously used the technique to make mid-infrared quantum cascade lasers (that is, at shorter wavelengths). Hu and Williams adopted it to build THz quantum cascade lasers.

“You design your laser material by building stacks of semiconductor layers one by one, one atom thick at a time,” he says. “Eventually, it becomes quite thick — say 10 microns thick — which is not quite visible size, but getting close. And then you build it into a little chip. At the end of the day, you hook it up to a battery or a power supply, and then it generates the light.”

At UCLA, Williams directs the Terahertz Devices and Intersubband Nanostructures Laboratory, which is broadly focused on the study of device physics. “We work in the area of materials and photonics, where we are looking at making new types of materials, devices, and systems in the terahertz and infrared frequency range,” he says. “We’ve been focused a lot on the electromagnetics and making the lasers, shall we say, useful. You spend all this effort to generate those terahertz photons. You need to get them out before they’re reabsorbed. You want them coming out in a nice, quality beam. So what you have is something that looks more like a nice pointy beam that

you would get from a laser pointer, rather than something that shines your light in all directions, or even worse, doesn’t let the light out at all.”

Williams and his colleagues have been working on engineering electromagnetic structures to improve output efficiency and beam quality and to make the wavelength tunable and changeable. The aim is to “essentially control all the properties of the light coming out,” he says. In July 2018, Williams and colleagues reported in *Applied Physics Letters* on the successful development of a THz quantum-cascade vertical-external-cavity surface-emitting laser (QC-VECSEL) whose output power is scaled up to watt-level using an amplifying surface designed to increase power density.

Once these lasers are out of the laboratory and in the world, they will be useful in a wide variety of disciplines, Williams says. One example: astrophysics. “These lasers may end up being a critical component for radio telescopes in the terahertz range that look into star-formation processes,” he says. “You point your telescope at the regions where stars are forming, which are mostly made up of gas and dust, and gently glow with terahertz radiation. Analysis of the terahertz radiation can tell you what the chemical compositions are, how warm things are, and how the clouds are collapsing to form stars.”

Other applications have more to do with imaging *through* things for nondestructive evaluation or testing — for instance, being able to see through coatings or papers or packaging for food-inspection or security-screening purposes, he says. The lasers also could have applications in medicine and in spectroscopy.

Defense is another potential application. If the technology behind the THz QC-VECSEL could be adapted to make shorter wavelength lasers in the mid-infrared, they could be used to “confuse a heat-seeking missile fired at your plane by pointing a laser at it and blinding the sensor,” Williams says. “But you have to have a laser that’s powerful enough and a good enough beam.” His lab doesn’t have any results on that application yet, but they’re working on that, among other possibilities. “Basically, we’ve come up with this new approach in the terahertz, and we are trying to push it as far as we can,” he says.

Thinking back to his early days in science, Williams says he wasn’t really planning on continuing in academia — until the laser worked. “And then I thought, this is actually kind of fun. We were one of the first groups to make these terahertz lasers work. We were in a real horse race with some other groups. Then I went off to UCLA, and we’re doing similar, but not exactly the same things. So [Qing Hu] and I are still working partially in the same space. And that’s fun, too.” 🇺🇸



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RISING STARS IN EECS IN 2018

In October 2018, 76 outstanding EECS graduate students and postdocs from around the world gathered at MIT for an intensive two-day workshop on academic careers. Following are some scenes from the event.



Rising Stars workshop technical co-chairs (L to R): Professors Stefanie Mueller, Virginia Vassilevska Williams, Farnaz Niroui, and Vivienne Sze. Photo: Gretchen Ertl



Rising Stars "Words of Wisdom" panelists (L to R): Professors Ronitt Rubinfeld, Polina Golland, Muriel Medard, Daniela Rus, and Dina Katabi. Photo: Myung-Hee Vabulas



Workshop participants came from more than 25 universities and companies. L to R, Suguman Bansal of Rice University, Sarah Chasins of UC Berkeley. Photo: Justin Knight



Anette "Peko" Hosoi, associate dean of engineering and the Neil and Jane Pappalardo Professor of Mechanical Engineering at MIT, spoke to attendees about teaching. Photo: Justin Knight



Rising Stars participants presented their research in a poster session during the workshop. Photo: Gretchen Ertl



Professors Azita Emami of Caltech and Ranjitha Kumar of the University of Illinois at Urbana-Champaign were among those who spoke on career trajectories. Photo: Gretchen Ertl

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