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MASSACHUSETTS INSTITUTE OF TECHNOLOGY SPRING 2015

The View from Here

MIT takes a new look at the future of innovation

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Spring 2015

THE MIT SPECTRUM is a newsletter distributed without charge to friends and supporters of the Massachusetts Institute of Technology by MIT's Office of Resource Development.

ON THE COVER
MIT and the Kendall Square neighborhood form the densest innovation cluster in the world.

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Innovation at MIT

AT MIT, WE SEE INNOVATION AS THE PROCESS OF TRANSLATING KNOWLEDGE INTO PROGRESS. That can mean something as useful and appealing as a well-considered app—or something that turns the world upside down. The first microchip. The laser. GPS.

As the people of MIT have demonstrated time and again, often the most profound and fertile innovations spring from the seeds of fundamental research. This issue of *Spectrum* highlights individuals at work on intriguing new examples, from Professors John Joannopoulos and Marin Soljačić, physicists who helped develop a new method for wireless power transfer, to electrical engineering Professor Jim Fujimoto, who pioneered optical coherence tomography, a major new form of medical imaging that offers real-time visualization of internal tissue microstructure and pathology using echoes of light.

You will also find a story on MIT.nano, the ambitious new facility soon to rise in the heart of our campus. Providing advanced facilities for nanoscale research and engineering, MIT.nano is also designed to create connection and inspire collaboration across the broad community of nano researchers in and around MIT. After decades of exploring the new ways that materials behave at the nanoscale, the time has come for action: transforming that knowledge into bold new progress in energy, environment, electronics, manufacturing, human health, and more.

The lessons of innovation and entrepreneurship have always been in the air at MIT. But for most of our history, they were not in the curriculum. Today—in response to rising student enthusiasm—MIT offers a wide range of resources, including courses, competitions, mentors, and maker spaces, to help students build the skills to invent new products, launch new companies, and deliver their ideas to the world. Expanding and enhancing those resources is a central aim of our new Innovation Initiative.

In the end, at MIT, innovation is simply how we approach the world—*Mens et Manus* in action. It shapes how we teach our students and collaborate with partners here and around the globe. And because our faculty, students, postdocs, and alumni approach the challenge of innovation in the spirit of our mission statement—bringing knowledge to bear on the world's great challenges, to benefit humanity—I believe we have the power to make a disproportionate positive impact.

I look forward with excitement to seeing where the people of MIT lead the world next.

Sincerely,

L. RAFAEL REIF

Announcing the MIT Innovation Initiative

WHAT WILL MIT'S INNOVATION INITIATIVE LOOK LIKE? By definition, there will be surprises along the way. But the contours of this new effort—laid out in the December 2014 preliminary report "The MIT Innovation Initiative: Sustaining and Extending a Legacy of Innovation"—make one thing clear: it's a natural extension of MIT's established culture of creative, collaborative problem solving.

"Innovation is the art of transforming knowledge into progress and prosperity. We aim to elevate and accelerate that art form—and to make it a science—in service to the world." —L. RAFAEL REIF

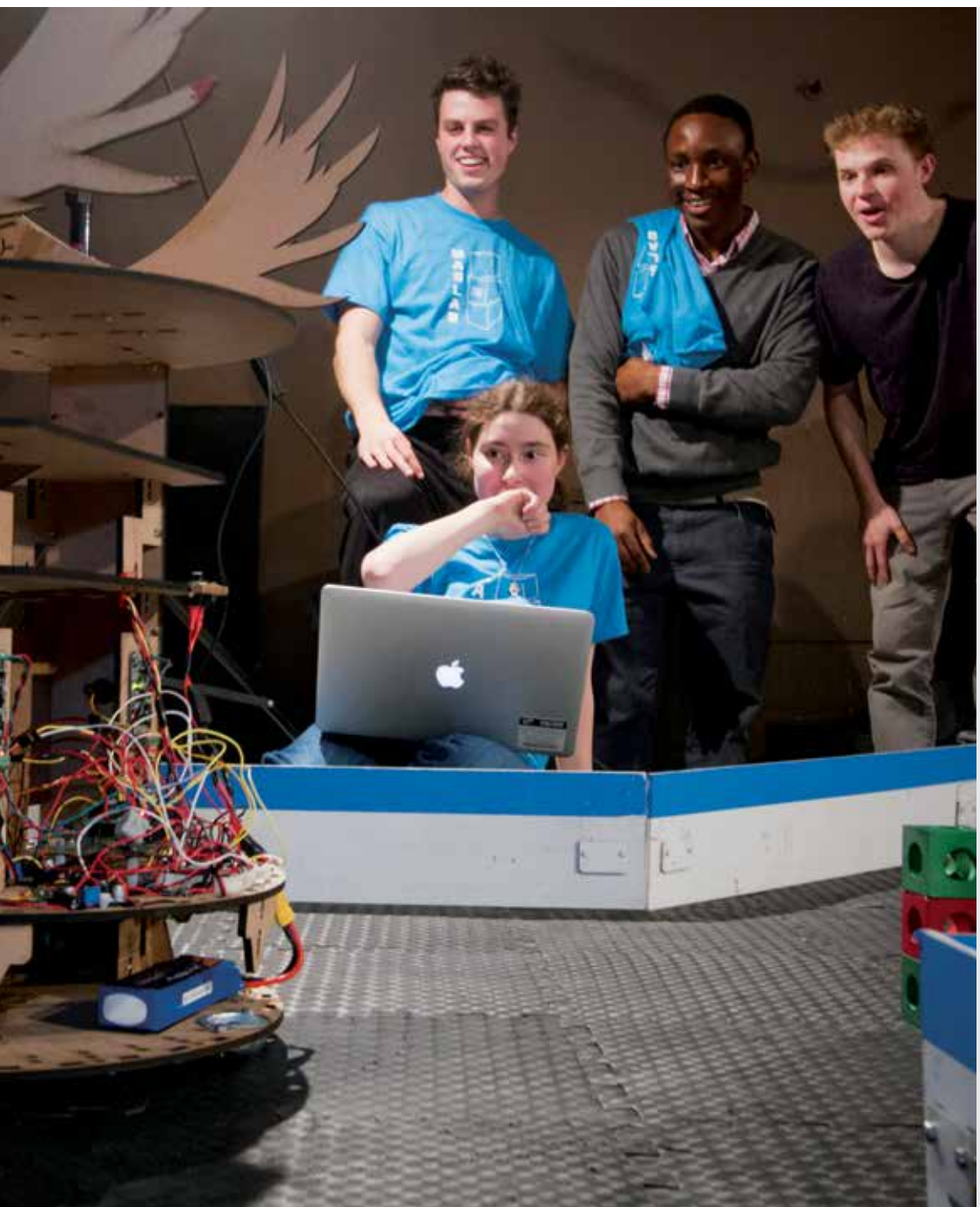
The Innovation Initiative is co-directed by Vladimir Bulović, the Fariborz Maseeh Chair of Emerging Technology, and Fiona Murray, the William Porter Professor of Entrepreneurship. The two professors are also associate deans for innovation in the School of Engineering and the MIT Sloan School of Management, respectively. (See interview page 5.) Under their leadership, a faculty committee from all five of MIT's schools answered MIT President L. Rafael Reif's charge to define the scope and goals of the new initiative. The resulting proposals in December's report fall into the categories of *capabilities* (seeding the world with innovators); *communities* (engaging the full spectrum of stakeholders); and *convening* (creating physical and digital spaces that promote a culture of innovation). The report also includes the development of a new Laboratory for Innovation Science and Policy (see sidebar) that will take a multidisciplinary approach to analyzing and understanding the innovation process, and so provide the evidence base for the initiative's proposed changes.

Another way to look at MIT's Innovation Initiative is in terms of opportunities to support and educate the next generation of innovators. For MIT faculty, postdocs, and students, this could mean additional innovation-focused spaces and new sources of funding to test their ideas out in the world as an integral part of their research and/or education at MIT. Undergraduates may select a minor in entrepreneurship and innovation to complement their major course of study. The entire MIT community will benefit from the inclusive perspective of a new Women in Innovation, Science, and Entrepreneurship Program, and from interaction with Visiting Innovation Fellows—leaders from the spheres of industry, academia, government, and risk capital. (The first such fellow, announced in January, is former Massachusetts Governor Deval Patrick.)

The Institute will make an ambitious investment in facilities dedicated to generating, sharing, testing, and refining new ideas. These will range from small maker spaces distributed across campus to a state-of-the-art center for nanoscale research and prototyping. Already under construction, MIT.nano (see page 6) will also become a hub for partners from the start-up and corporate sectors to join forces with MIT's "nano makers."

Like-minded innovation communities—particularly groups of alumni on the West Coast and outside the US—will find new ways to engage with MIT's community of innovators through a global network of "innovation nodes." Online points of connection will expand participation in the initiative further still, sharing MIT's hard-won insights into the workings of innovation with online learners through MITx, and creating new avenues for all members of the MIT community to locate the collaborators, resources, and expertise they need to convert their novel ideas into tangible change.

— NICOLE ESTVANIK TAYLOR



Pioneering the Science of Innovation

INSPIRATION, SERENDIPITY, DISCOVERY, GENIUS. All terms associated with innovation, collectively conjuring an air of mystery. At MIT, however, another set of words also comes up: data, method, metrics. In the words of President L. Rafael Reif, "Innovation is the art of transforming knowledge into progress and prosperity. We aim to elevate and accelerate that art form—and to make it a science—in service to the world."

Building upon a robust body of scholarly and practical knowledge, the MIT Innovation Initiative has announced it will create the Laboratory for Innovation Science and Policy to pioneer the emerging science of innovation—defined as "the systematic analysis and understanding of the conditions that shape innovation outcomes." The laboratory will bring together investigators across many disciplines to map the DNA of the innovation process; develop new ways to measure and examine the elements of innovation; codify evidence-based insights into best practices that will be shared with the MIT community and the Institute's colleagues in business and academia; and inform governmental policy on a global scale.

LEFT At a recent racecar robotics class are: (left) Maxwell Lancaster, Tomi Adelusi, Elliot Owen, and Katy Muhlrad (front).

PHOTO: LAUREN OWENS

Why an Innovation Initiative Now?

MIT has a long history as an innovation powerhouse, so why does it need an innovation initiative now? For an explanation, *Spectrum* asked Vladimir Bulović and Fiona Murray, co-directors of the MIT Innovation Initiative and associate deans for innovation in the School of Engineering and the MIT Sloan School of Management, respectively.

BULOVIĆ: "The Innovation Initiative is driven by our students' demanding from us a change—change in the way we educate them to be more effective. We live in a new age focused on immediacy. Technology allows us to be much more connected, and consequently, Millennials have much more awareness of social needs. The ability to access information 24/7 has led young people to say, 'I can make a difference. And I want to do that now, rather than wait until I graduate.'"

MURRAY: "MIT students today have a very different view of their careers, what sorts of organizations they want to work for. It's no longer a view that you necessarily work for one organization for your entire life and wait 25 years before you can have a project of impact in the world. And they also often want to build their own organizations. Given this, students are asking, 'Which institutions are going to educate me to be a global innovator in the most effective way?'"

BULOVIĆ: "The Innovation Initiative brings forward in a coherent way what MIT has done ever since we formed as an Institute. We have always looked forward, asking, 'How do we reimagine the world? How does the world get better through our next action?' Today, those questions are being asked again by students, who want their next action to make a *difference* in the world."

MURRAY: "MIT is very much at the forefront, saying, 'Yes, you still need a deep disciplinary education in engineering, science, or social science, but we also want to give you a more well-defined set of tools, expertise, and capabilities to have an impact in the world more rapidly and effectively. And we want to give you a place to practice.' As educators, we need to encourage openness to experimentation, to encourage all students to try things, to learn to fail, and to try again. And we have to create the portfolio of projects and activities that allow students to do that, and in doing so, build their confidence and leadership skills as innovators."

"Technology allows us to be much more connected, and consequently, Millennials have much more awareness of social needs."

BULOVIĆ: "Our students are really asking us to develop with every one of them a project portfolio, a set of experiences that are quantifiable beyond grades, that at the end of their MIT education they can point to and say, 'I changed a life through my action' or, 'I developed this piece of software that made life better for this set of people.' They want to be constructive in the world, and if we can give them the tools to do that, if we can be creative enough with them to reimagine what that education is, we would help advance the world tremendously." — LIZ KARAGIANIS

ABOVE Fiona Murray and Vladimir Bulović say the Innovation Initiative is driven by students' demand for change.

PHOTOS: LEN RUBENSTEIN

Introducing MIT.nano

LEFT Extraordinary potential for game-changing innovation is why MIT is placing a big bet on small with construction of MIT.nano, a 200,000-square-foot nanoscience and nanotechnology facility.

RENDERING: WILSON ARCHITECTS

IMAGINE IF YOU LIFTED UP a corner of the periodic table and discovered underneath another version of the table—one that lists the same elements, but with entirely new properties for the compounds and materials they form.

That's the tantalizing promise of nanotechnology, and over the past decade researchers have made remarkable advances in our ability to observe, manipulate, and design materials measured in billionths of a meter. Take carbon, for instance. At the human scale it's graphite, the brittle core of a pencil. But form graphite into a sheet just one-atom thick and you have graphene—an incredibly conductive substance that is also 200 times stronger than steel.

This extraordinary potential for game-changing innovation is why MIT is placing a big bet on small with the construction of MIT.nano, a 200,000-square-foot nanoscience and nanotechnology facility, says Vladimir Bulović, the Fariborz Maseeh Chair of Emerging Technology and associate dean for innovation in the School of Engineering. "The work that we do inside this new facility will impact some of the most important challenges of our time," says Bulović, who is also the faculty lead for the project. "Issues of energy, medicine, the development of new computational paradigms. Building blocks for new materials. Accelerating manufacturing as we know it. And underlying all that, quantum science and technology."

MIT.nano will place a single, comprehensive facility for researching nanoscale materials and processes in the heart of the campus. And its central location—adjacent to the Great Dome on the site of Building 12—is no accident: when the doors open in 2018, MIT.nano is intended to serve as a shared resource for more than 2,000 researchers per year from departments across MIT.

Because the tiniest vibration can derail such sensitive work, the building's basement will be the quietest place on campus, designed to minimize mechanical and electromagnetic noise. And because a single speck of dust is a wrecking ball for nanoscale experiments, the building will have two levels of interconnected clean rooms. A prototyping facility for translating ideas and discoveries into handheld devices will sit on the top floor.

"MIT.nano will house the most complex set of nanotechnology tools ever assembled in a single place. Tools no individual investigators or labs would be able to afford on their own," says Bulović. "And as a result, the entire community will have access to an incredible resource that will propel all of us forward.

"MIT.nano will be critical for research. But as important, it will enable us to provide education like we have never been able to deliver before. The new sets of nano tools inside our MIT nano facility will be a perfect training ground for both our graduate and undergraduate students."

Beyond the tools, Bulović expects the central location and shared access to spark innovation simply by encouraging interactions among its users. "MIT.nano will enable convergence of disciplines. It will bring together physicists, chemists, material scientists, biologists, engineers—electrical, mechanical, civil, nuclear—all in the same place where they can go ahead and build the 21st century," he says.

"We are extremely cognizant that we only have two products as a university: knowledge and people," says Bulović. "Through MIT.nano, we'll make them both much, much better."

— TOM GEARTY

"It will bring together physicists, chemists, material scientists, biologists, engineers—electrical, mechanical, civil, nuclear—all in the same place where they can go ahead and build the 21st century."

READ MORE

Grad students getting kids excited about nano
spectrum.mit.edu/webextras

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mitnano.mit.edu

Innovation Resources Abound at MIT

Because innovation is everywhere at MIT, there's an abundance of resources to teach, foster, and support it, from classes and competitions to clubs and global activities.

Classes

There are **more than 50 innovation and entrepreneurship classes** across all five schools at MIT.

More than 3,000 students—out of 11,000—take an innovation or entrepreneurship class each year.

Mentorship Opportunities

Through the **MIT Venture Mentoring Service**, alumni volunteers advise MIT entrepreneurs on how to begin and sustain a business.

Programs

The **MIT Undergraduate Professional Opportunities Program** (UPOP) attracts more than 50% of MIT sophomores to pursue industrial experiences year round.

The **Gordon Engineering Leadership Program** is a two-year program that develops the character, initiative, and self-efficacy of more than 20% of engineering undergraduates.

More than 300 MIT students from all schools and degree programs applied to the Summer 2014 **Founders' Skills Accelerator Program**.

Clubs

There are **more than 40 clubs** committed to innovation and entrepreneurship.

Competitions

The **MIT $100K Entrepreneurship Competition** attracts more than 1,000 students and more than 250 teams each year, challenging them to turn ideas into successful companies.

Moving Ideas to Market

The **Technology and Licensing Office** offers advice to MIT students and faculty on licensing their technologies and obtains invention disclosures and patents across campus.

Maker Spaces

The **Edgerton Center Machine Shop** is a workspace to support student invention.

Students learn the ancient art of glass blowing at the **MIT Glass Lab**, and when art meets science, it can lead to scientific and engineering insights.

The new **MIT.nano facility** will bring together more than 2,000 MIT researchers and their external collaborators.

Global Activities

MIT G-Lab, D-Lab, and **MISTI** are among many courses and programs that enable students to engage with innovation-driven activities around the world.

Students travel overseas each year through programs at the **MIT Public Service Center** to work on innovative solutions to global poverty.

Centers

The **Martin Trust Center for MIT Entrepreneurship** provides expertise and resources for students to develop strong entrepreneurial capabilities.

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For more MIT innovation and entrepreneurship resources, visit: spectrum.mit.edu/webextras

PHOTO: CHRISTOPHER HARTING

Discovery Research Is Reinventing the World

"WITHOUT DISCOVERY RESEARCH, without innovation, applied research can only go so far," says Institute Professor Phillip Sharp. "There are strikingly important things we just don't know exist, but discovering them through basic science changes the whole world."

That's precisely what happened to Sharp. He came to MIT in 1974 to join the Center for Cancer Research, now the Koch Institute for Integrative Cancer Research, where he conducted discovery research on the molecular biology of gene expression. Three years later, he discovered RNA splicing, which changed scientists' understanding of the structure of genes, and in 1993, he won the Nobel Prize.

His discovery was part of the foundation for Biogen, now Biogen Idec, which he helped launch in 1981. The company is a world leader in synthesizing therapeutics to treat cancer and multiple sclerosis and was the catalyst that helped launch the biotechnology revolution.

LEFT Phillip Sharp's discovery research led to invention of RNA splicing, the Nobel Prize, and the founding of Biogen, which helped spark the biotechnology revolution.

PHOTO: LEN RUBENSTEIN

"Fundamental discovery in biological science and its translation into science in the US takes about 10 years," Sharp says. "In the life sciences, fundamental research is the gatekeeper for advancing treatment and controlling disease. No question."

Discovery research can lead to applications, new companies, jobs, economic growth, and competitiveness in the world, says Michael Sipser, dean of the School of Science. "With more basic science, there are more discoveries, more ideas, and more raw material for people to come up with new products, new companies, new solutions."

In fact, MIT has long been a force of innovation precisely because so many MIT discoveries enter the marketplace, he says, partly because of MIT's Technology and Licensing Office, which makes licensing and patenting easier; partly because of the MIT Sloan School of Management and the MIT Media Lab ("scientists partner with entrepreneurially minded people"); and partly because of MIT's culture of cross-disciplinary research, blurring the boundaries between the Schools of Engineering and Science. As a result, he adds, MIT leaders have transformed Kendall Square into a leading innovation cluster in the world.

"If it weren't for basic science, we'd still be in the Stone Age," Sipser says. "We've always needed science and we always will. Science helps us find new ideas, and problems need new ideas to be solved."

"If it weren't for basic science, we'd still be in the Stone Age. We've always needed science and we always will."

Maria Zuber, MIT's Vice President for Research and the E.A. Griswold Professor of Geophysics, adds that now more than ever, we need basic research to solve the great mysteries of our time—how the brain works, the search for life on other planets, the nature of dark matter, and more. And yet, federal funding in basic research is declining, she says, adding that in 1960, 55% of MIT's campus revenue came from federal research dollars. By 2013, that figure fell to 22%.

"The federal government historically made the investment in basic science, and now they're cutting back. Are we going to have the array of advances in basic science needed to address problems of the future? When you cut back on basic science, it affects practical world problems. You might not see an answer a year from now, but 10 years from now you will."

Problem solving is not the only reason to fund discovery research, Sipser says. Without it, we risk our technological edge in the world; we lose brilliant people to institutions where they're better supported; and it's trickier for faculty to embark on high-risk research, because they instead favor more certain outcomes.

"We need breakthrough research now more than ever," he says. "The country's leadership in the world depends on it."

— LIZ KARAGIANIS

Kendall Square

A Global Center for Innovation Grows Alongside MIT

Kendall Square in the 1970s was a mass of old factories, abandoned buildings, vacant lots, and chain link fences, says Institute Professor Phillip Sharp, "and if you were wise, you didn't walk around by yourself at 10 o'clock at night."

But now this East Cambridge neighborhood is an innovation powerhouse, a hotbed of new ideas, new technology, and know-how, and it is teeming at midday with technologists and entrepreneurs. Today, Kendall Square hosts 150 high-tech companies, including some of the most celebrated life science, technology, and pharmaceutical companies on earth, such as Biogen Idec, Genzyme, Novartis, Akamai, Google, Amazon, and Microsoft.

"What makes it unique is in a few square miles, you have an enormous concentration of start-ups, high-tech companies, and venture capital firms."

President John F. Kennedy wanted to build NASA's Electronics Research Center in Kendall Square. It opened in 1964 but closed five years later because of budget cuts. "That left this big void, so MIT then partnered with the City of Cambridge to advance plans to revitalize Kendall Square," says Provost Martin Schmidt, co-chair of the Building Committee, which now has big plans to further develop this booming innovation cluster.

"Kendall Square is the epicenter, but the reach is all around the edge of campus," Schmidt says, adding that with the input of hundreds, a plan has been designed to create "a gateway" and "a sense of destination" in Kendall Square, so that when you rise up out of the subway, it will be visibly clear that you've entered the MIT campus.

Soon to come, he says, will be academic space, graduate dormitories, a childcare center, and the new home of the MIT Museum. Also slated over the next decade is innovation space, high-rise housing, retail and commercial space, all with landscaping and underground parking. "We see it as an opportunity to further enliven the area. It will become a place to go, rather than a place just to walk through," says Schmidt, who has cofounded or co-invented the core technology for six start-up companies.

"Every state in the country wants an innovation center like Kendall Square, so we've been lucky that we were first," says Sharp, who launched Biogen here in 1981, triggering the biotechnology industry as well as the renaissance of Kendall Square (see page 8).

"Kendall Square is the densest innovation cluster in the world," Schmidt says. "What makes it unique is in a few square miles, you have an enormous concentration of start-ups, high-tech companies, and venture capital firms. What makes Kendall so interesting to watch is its proximity to the surge of talent at MIT, the universities, and the hospitals," he says. "You have to assume that that's going to translate to significant advantage in terms of all the serendipitous interactions that are going to occur."

Sharp adds that MIT has long been expert at translating basic research into the marketplace. "We're not here just to gain new knowledge; we're here to transfer that new knowledge into useful things," he says. "It's what made Kendall Square Kendall Square." — LIZ KARAGIANIS

ABOVE Kendall Square is an innovation center for the world.

PHOTO: GAO GUANGYAN

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From the 1800s to today: Made in Kendall Square
spectrum.mit.edu/webextras

In Praise of Building

MIT's Maker Czar Celebrates Hands-On Learning

MARTIN CULPEPPER REMEMBERS spending five days a week in an MIT machine shop as he worked on the projects that would earn him two MIT degrees in mechanical engineering. He often came home smelling of oil.

"I think building is really important. It helps us learn," says Culpepper, now a professor in that department. "I built many machines that didn't work. Then I'd figure out what I'd done wrong with the math and physics and try again. Eventually, I succeeded."

Culpepper now says that making things is key to innovation. "You can think about how you might do something, but cogitating will only get you so far. Sometimes it takes building a prototype to have that Eureka moment" where everything falls into place. Access to a prototype can also work in reverse, giving the inventor great ideas for other potential applications.

Hands-on learning has always been part of MIT's culture, he says. So it's not surprising, he estimates, that MIT has more square feet of "maker spaces," or places equipped for building things, "than any other university on the planet"—at least 15 major maker spaces on campus by his reckoning, including the Hobby Shop, Edgerton Center, and the Center for Bits and Atoms.

"We're in the midst of revamping the way we think about these spaces and how we run them," says Culpepper, adding that the country itself is experiencing a kind of "maker revolution." At the helm of the MIT effort is Culpepper, who last year was named Maker Czar for the Department of Mechanical Engineering, and who will soon work on similar problems for the entire Institute. It is his job to figure out how to make MIT's maker spaces more productive and accessible.

One step to that end, he says, is increasing the number and size of maker spaces that are run by graduate students. That would help tackle one barrier to helping students make things: access to maker spaces in off hours when technical staff aren't around but students are active.

"With proper training graduate students can take on a variety of activities," Culpepper says. He notes that students handled safety, budgeting, planning, and more for the Institute's first Maker Faire last fall. That event, which attracted nearly 3,000 attendees, featured more than 100 exhibits exploring the fun of making everything from instruments to robots.

Daniel Dorsch, a graduate student in mechanical engineering, says: "The chance to apply your skills to a real-world problem teaches you firsthand more than what can be learned in the classroom."

"You can think about how you might do something, but cogitating will only get you so far. Sometimes it takes building a prototype to have that Eureka moment."

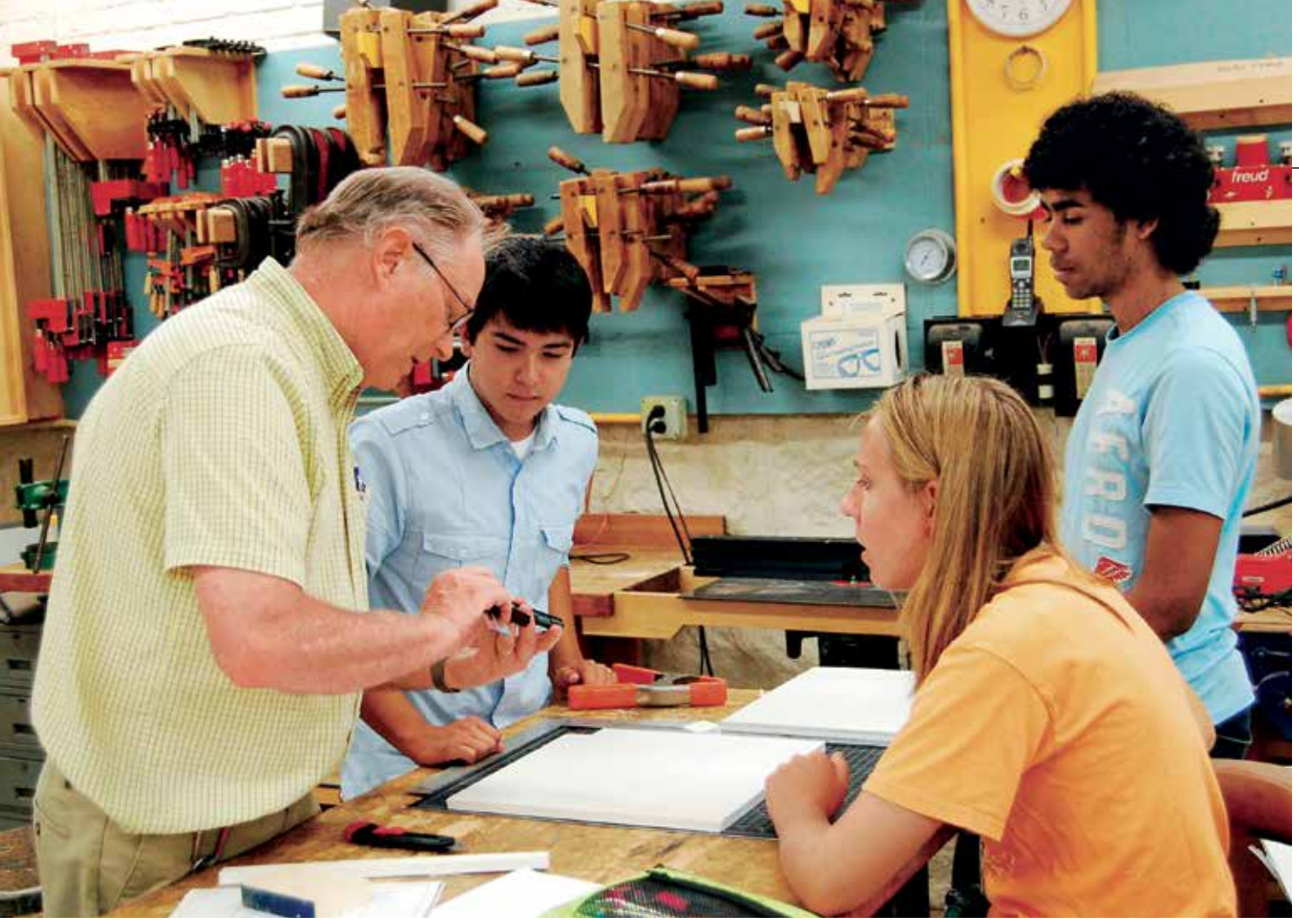
Culpepper, along with MIT's Information Systems and Technology, is also developing a Maker App that began as an effort to catalog the maker spaces and maker equipment on campus. Right now, he says, "if you're in one maker space and it doesn't have the machine required to build a given part, you're stuck. But that machine may just be three buildings away." His team is also looking at using the app to track the usage of machines in different maker spaces. "The software will give us insights into where to make changes so that our maker spaces work even better." For example, MIT might add more machines that are in high demand.

Ultimately the idea is to share the app—and its results—with others, Culpepper says. "The big bang for the buck engineering-wise is when the software gets adopted by other universities and they start building and refining their own maker spaces; then we can learn back from them."

— ELIZABETH THOMSON

LEFT Martin Culpepper says that making things is key to innovation.

PHOTO: LEN RUBENSTEIN



Making It at MIT

Founded as a student club in 1938, the MIT Hobby Shop's name suggests a folksy workshop. But today this busy facility is anything but quaint—it's an essential element in MIT's culture of innovation and hands-on making. Its members pursue hobbies—from designing furniture to crafting musical instruments—but the Hobby Shop also bursts with entrepreneurial activity, as they invent, prototype, and launch start-ups to bring their innovations to the marketplace.

"What's unique about the Hobby Shop," says director Ken Stone '72, "is that it is open to all MIT students, faculty, alumni, and staff, and is not connected to any department or lab. We encourage anyone who wants to build, and we give them the space, instruction, and equipment to do it."

Since the Shop began tracking use in 1994, it has attracted more than 4,700 members, with 89 new members last fall alone. The Hobby Shop also supports specific classes, including *Product Design and Development*, a joint MIT Sloan and Mechanical Engineering course.

When Ben Polito '99, president and cofounder of Pika Energy, launched his renewable energy company in 2010, he initially used the Hobby Shop to build and test wind turbine blades. "We built prototypes of wind turbines, made generators, shafts, and castings," says Polito. "We even prototyped our manufacturing process there. It is fair to say that in its formative years, Pika Energy was built at the Hobby Shop."

Newly expanded and renovated, the Hobby Shop has a spirit of creativity and community. In addition to traditional woodworking and metalworking tools, it has a new 4 × 8 foot computer-controlled router; a water jet capable of cutting materials from titanium to granite; a new welding area; and a computer design room with a 3-D printer.

When Pranay Jain, a graduate student in Mechanical Engineering, arrived at MIT in 2013 he headed for the Hobby Shop. His idea was to make a caliper for blind users that can make measurements as fine as one sixteenth of an inch. His new product, the Tactile Caliper, has a mechanical slide that forms Braille dots as it moves so it can be read by touch.

"I created a prototype, but a critical piece of the plastic instrument failed," says Jain, a research fellow at the Tata Center for Technology and Design at MIT. "I couldn't understand why. One professor suggested I make it out of stainless steel. I had never cut sheets of metal with such precision. I showed the design to Ken, and he said, 'Let's give it a shot.' And it worked perfectly."

Jain and his business partner Anshul Singhal, a fellow graduate student in Mechanical Engineering, have placed an order with a manufacturer for 10,000 Tactile Calipers, taking the invention from idea to product in 18 months. The National Braille Press recently honored the duo with the Touch of Genius Award for Innovation. And they have other products in the works.

ABOVE "We encourage anyone who wants to build, and we give them the space, instruction, and equipment to do it," says Ken Stone, shown at left with students.

PHOTOS: DIVISION OF STUDENT LIFE; LAUREN OWENS

"It is fair to say that in its formative years, Pika Energy was built at the Hobby Shop."

Ken Stone sees the growing popularity of maker spaces as a trend. "MIT has always been a leader in this field. It seems the rest of the world is catching on to a core value of an MIT education—that is, the 'manus' part of 'mens et manus', i.e., mind and hand."

"The Hobby Shop is not just a machine shop, it's a community," says Jain. "You get to know what other people are making, and get a lot of help. The Hobby Shop is central to the community of innovators and makers at MIT. For me, it's a ladder of growth."

— LAURIE EVERETT

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Hobby Shop start-ups spectrum.mit.edu/webextras

Holding Governments Accountable

The MIT Governance Lab launched in August 2013 to connect those on the front lines of political activity with scholars conducting rigorous academic research. Led by Associate Professor of Political Science Lily Tsai, MIT GOV/LAB employs five PhD students and two project managers, and projects are already under way in Bangladesh, Guatemala, Kenya, the Philippines, Liberia, Tanzania, Uruguay, and the United States. Tsai discusses this new initiative with *Spectrum*.

What was your inspiration for launching the Governance Lab?
A few years ago, I had the fortune of going to the village where my mother spent the first few years of her life in China. I was able to see the mud brick house that my grandfather built with his own hands, and it was basically unchanged after six decades. There was still no running water and no electricity.

Seeing this village really illustrated how hard work by individuals does not build roads, provide infrastructure for running water, or lead to better schools. In other words, poverty and development are not just—or even primarily—economic problems. In many developing countries, huge amounts of aid don't seem to make any difference—and that's because money is not the issue.

Fundamentally, poverty and development are political problems. My personal motivation for starting Governance Lab was to help figure out how to make governments more accountable and responsive to their citizens. This is important not just because it is what democracy is all about, but also because it's impossible to get better development unless we increase citizen voice and increase government accountability.

What's innovative about the work of the Governance Lab?
Innovation is not just about technology. A key part is social and political: Technology has to work in real contexts. So, for example, we're collecting data on the political and social impacts of the Ebola crisis in Liberia, where the stigma of survivors is becoming a huge concern. What do people think the policies toward survivors should be? What is the impact of government outreach on safe burial practices? How do you get more citizen cooperation in a crisis situation when people don't trust the government?

At the GOV/LAB, we work with partner organizations to design, pilot, and evaluate programs. Our relatively small-scale, short-term investigations provide information that's operationally useful—so that they can make mid-course corrections. In Liberia, for instance, we're working with an NGO [nongovernmental organization] that is trying out different kinds of outreach to officials; we will then assess what factors make citizen-government cooperation more likely.

What benefits do graduate students gain from working on Governance Lab projects?
MIT attracts students who want to combine academic research with work that has a direct impact on policy and the real world. GOV/LAB provides hands-on research experience early in a student's graduate career with the added benefit of faculty guidance. Our students play a substantive role: They have a hand in identifying research questions and often serve as co-investigators or co-project leads. Not only do GOV/LAB students contribute theoretically to political science, they also generate findings that are directly useful to donors, NGOs, and other stakeholders whose work has a profound impact on people's lives. — KATHRYN M. O'NEILL

ABOVE Ben Armstrong says research reveals that citizens who weigh in online have different views from those who attend town meetings.

PHOTO: BEN BOCKO

GOV/LAB at Home

BEN ARMSTRONG knows firsthand that technology can be used for good or ill. A native of the industrial Midwest, where for many "technology" is the bad word behind the loss of good jobs, he has also worked in Silicon Valley, where "technology is perceived as the hammer for everything."

Today, as a PhD student at the MIT Governance Lab (GOV/LAB), Armstrong is trying to find the sweet spot where innovation makes a positive difference. "Technology companies don't have the resources to study whether what they are doing is having the intended effects," he says. "What GOV/LAB can do is put these organizations to the test."

Armstrong has been helping Pittsburgh evaluate a program designed to boost civic engagement in the wake of a major police corruption scandal. City leaders worked with the technology company MindMixer to launch an online public forum where citizens can air safety concerns. At the same time, they also scheduled traditional town meetings around the city—providing GOV/LAB with an ideal opportunity to study the relative value of the new communication technique.

The research quickly revealed that citizens who weigh in online have very different outlooks from those who attend town meetings. "People online were really concerned about traffic and bike lanes. People in person were worried about violence and guns," Armstrong says. GOV/LAB also discovered that while public officials find the online information useful and novel, they consider the in-person feedback more relevant to the city's problems.

The study is ongoing, but these early results have been reported to both Pittsburgh and MindMixer so they can improve their efforts going forward—which is one of GOV/LAB's goals. "We're doing randomized controlled trials in a different way—we call it iterative experimentation . . . . [This] allows us to influence decision making," says Armstrong.

"The long-term impact is really for government to get citizens more involved so that they have a responsive democratic system."
— KATHRYN M. O'NEILL

GOV/LAB Abroad

NINA MCMURRY was in South Sudan, working to improve governance in the war-torn nation in the wake of independence, when she realized she needed more skills and knowledge for the task.

"I really wanted to better understand the problems we were trying to solve and gain skills I could use to do rigorous research on the issues that we were working on there," McMurry says.

Attracted to MIT by the new Governance Lab's hands-on approach to research, she joined the PhD program in MIT's Department of Political Science, where she studies political accountability in weak states. "MIT really focuses on research to solve problems in the world, in addition to contributing to theoretical knowledge," she says.

At GOV/LAB, McMurry is working with a non-governmental agency (NGO) to improve the delivery of health-care services in rural, indigenous areas of Guatemala. The NGO has been employing a text messaging service to connect community leaders to the government officials responsible for resolving such issues as staff shortages, equipment failures, and lack of supplies. "These villages are very remote, so it's hard for them to communicate their needs," she says.

Such projects are becoming increasingly popular, McMurry says, but it is unclear whether they produce results. Her research, which she is conducting with fellow PhD student Benjamin Morse, addresses such questions as "What happens when you introduce this technology in a place where people are illiterate or have no access to technology? Who uses it? Are they the more advantaged?"

By looking at the broader social and political context of interventions, McMurry says GOV/LAB fills a key research gap. "It's important to look at which of these initiatives is likely to be effective," she says. "I think Governance Lab is a step in the right direction." — KATHRYN M. O'NEILL

LEFT Nina McMurry works to improve delivery of health-care services in rural Guatemala.

PHOTO: BEN BOCKO

ABOVE Lily Tsai, associate professor of political science, recently launched GOV/LAB.

PHOTO: BEN BOCKO

More GOV/LAB projects around the world

Bangladesh
Tsai and her team are evaluating a variety of initiatives in Bangladesh that are designed to increase the voice of those traditionally excluded from government decisions. GOV/LAB researchers are specifically assessing what incentivizes women and the poor to participate in local government meetings.

Collaborating organization: CARE Bangladesh

Kenya
In collaboration with an organization that provides information online about the performance of Kenya's parliamentarians, GOV/LAB is investigating how Internet users decide what information is most important and credible. This project is intended to help GOV/LAB's partner to design a web presence that not only informs Kenyans, but also inspires political action.

Collaborating organization: Mzalendo

Tanzania
In Tanzania, GOV/LAB researchers are evaluating the use of comic books to change how youths feel about a variety of issues, including political action. One goal of this project is to determine the best way to communicate political information to people who are disengaged and apathetic.

Collaborating organizations: Shujaaz, Well Told Story, and Twaweza

Philippines
GOV/LAB researchers are examining the effects of a program that trains community leaders in the Philippines to advocate for the interests of the poor and push for better public services from local government. This project explores whether building the capacity of community leaders can have the unintended consequence of prompting politicians to buy off leaders to mobilize support.

Collaborating organization: Concerned Citizens of Abra for Good Government

Uruguay
Researchers from GOV/LAB are investigating in what ways information and communication technologies can improve citizen-government relations in Uruguay. This project focuses on measuring how citizens' attitudes toward government change in relationship to the length of time it takes the government to respond to public information requests.

Collaborating organizations: Datos Abiertos, Transparencia y Acceso a la información, and Qué Sabés

Shining a Light on Disease

JAMES FUJIMOTO'S LAB is celebrated for leading the development of optical coherence tomography (OCT), a medical imaging technology that is analogous to ultrasound, except that it uses echoes of light to achieve ultrahigh resolution. It also doesn't require contact with the tissue being imaged, which makes OCT especially useful for imaging the retina. Today the technology is widely used in ophthalmology: tens of millions of imaging procedures are performed each year.

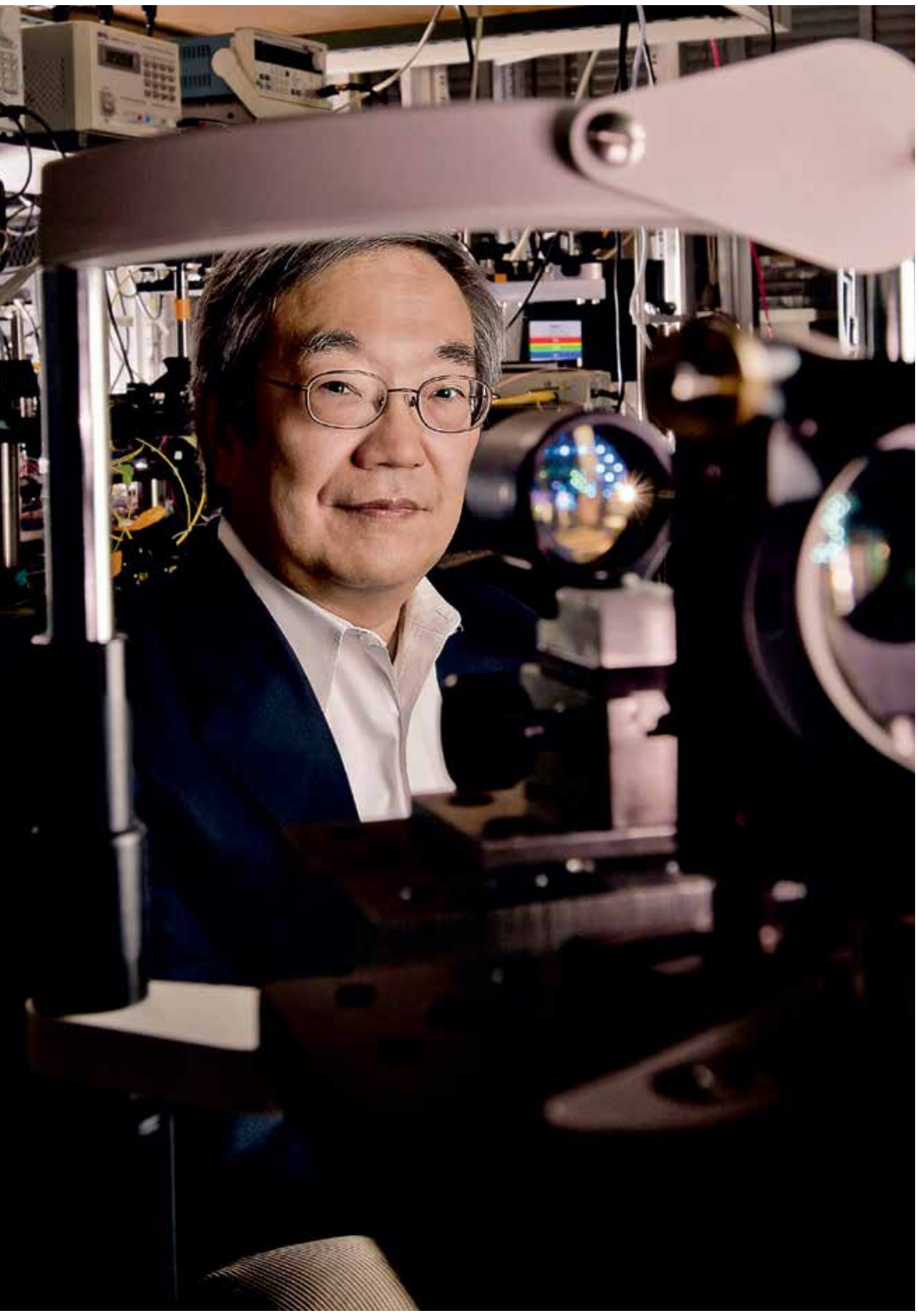
Fujimoto is the Elihu Thomson Professor of Electrical Engineering and Computer Science, and runs the Biomedical Optical Imaging and Biophotonics Group in the Research Laboratory for Electronics. He and his collaborators were recently co-recipients of the Champalimaud Vision Award, given for major breakthroughs in the alleviation of visual impairment and blindness.

Twenty-five years ago, Fujimoto's lab was working with ultrafast lasers, a key technology in physical sciences. Clinicians from Harvard Medical School approached Fujimoto with the idea of applying this technology to ophthalmology. David Huang, then a Harvard/MIT MD-PhD candidate in Fujimoto's lab, developed the concept for OCT during this collaboration.

For Fujimoto, running a successful lab is a matter of perspective—other people's perspectives. He is quick to deflect attention and credit his many collaborators. For him, building a diverse team is a prerequisite for conducting successful biomedical research.

"To develop a technology or procedure that has an impact on patient care fundamentally requires a multidisciplinary team of people," he says. So Fujimoto turned to Eric Swanson, then a satellite communications expert at the MIT Lincoln Laboratory, to help develop technology that could be used in the clinic. Other key collaborators were doctors Carmen Puliafito, then the director of the New England Eye Center, and Joel Schuman, a glaucoma specialist. Puliafito and Schuman performed clinical studies that demonstrated the efficacy of the technology.

The importance of outside perspectives hit home for Fujimoto when he was in high school. He'd developed an interest in electronics at a very early age and helped with his father's electrical contracting business. His parents were eager for him to go to college, since they did not have the opportunity themselves. They had been relocated to Chicago from California after their lives had been uprooted by the internment of Japanese-Americans during World War II. Given their experience, it didn't occur to them to let Fujimoto go to school out of state. It was only at the urging of a family friend, one of the few people they knew who had a university education, that his parents allowed him to apply to MIT.



"If we cannot create a team that transcends our individual limits of vision, then how can we have a positive impact in a field as complex as medicine?"

The work in Fujimoto's lab spans specialties ranging from endoscopy to pathology, and exemplifies the type of research MIT is known for, research that crosses disciplinary and organizational boundaries. His overarching goal, he says, is technology translation: to develop technologies that go beyond the laboratory and improve patient care. This requires close collaboration with clinicians and the business community.

"If we cannot create a team that transcends our individual limits of vision," Fujimoto says, "then how can we have a positive impact in a field as complex as medicine?" — ERIC SMALLEY

LEFT James Fujimoto's lab led development of optical coherence tomography (OCT), a medical imaging technology.

PHOTO: LEN RUBENSTEIN

Mobile Technologies to Visualize the City

DATA-DRIVEN STORYTELLING is the journalistic wave of the future. At websites like the *New York Times*'s *Upshot* and Nate Silver's *FiveThirtyEight*, writers are transforming numbers into visual narratives that illuminate modern life. MIT Assistant Professor Sarah Williams, director of the Civic Data Design Lab, is at the forefront of the movement.

She uses data, maps, and mobile technologies to develop interactive communications strategies that bring urban issues to broader audiences. Her work is crucial: she combines geographic analysis and design to make problems visible to policy makers. It's a new way of confronting civic challenges, especially in metropolitan areas.

"Data visualization brings a story to a broader group of people. Raw data is often too complex, it needs to be synthesized into something anyone can understand and used as evidence for developing civic change," she says. "I work at the intersection of technology, design, and policy. I'm excited about using technology in a creative way to effect change."

Take her recent project, "Industry in Motion." Here, she successfully used smartphones to crystallize and quantify the spatial network of New York City's Garment District.

In 2010, New York policy makers and fashion designers were at odds. Officials wanted to rezone the city's manufacturing hub to outlying areas. "The Garment District occupies high-value real estate," Williams explains. "Landlords could be making far more money." Designers argued that having manufacturers in close proximity was crucial to their billion-dollar industry.

To address the issue, the Design Trust for Public Space and the Council of Fashion Designers of America launched Made in Midtown, a comprehensive study of the fashion industry's presence in New York City with a focus on the Garment District. Williams was selected as a Project Fellow.

Williams and colleague Elizabeth Currid-Halkett designed an analysis to understand fashion workers' daily routines with additional funding from the Rockefeller Foundation. They used popular social media app Foursquare to track every movement of 100 willing fashion workers employed at design firms inside and outside the Garment District, documenting their day-to-day routines.

Through Foursquare check-ins, Williams and her team could actually visualize the workers' schedules. She found that 77% of all trips made by fashion designers across the region—and 80% of business trips—were logged within the neighborhood.

"We were able to prove that due to current clustering of fashion businesses in the District, people who had their stores or studios outside the district could do errands just as efficiently as those inside," she says. "These agglomerations are essential to economic activity."

Once restricted to surveys and spreadsheets, Williams is also democratizing the data-collection process through mobile devices. She says: "They help provide spatial evidence to back up research that once was only available through interviews. This is more of a quantitative approach," and one that's easily accessible to anyone with a phone. To that end, policy makers are better able to understand her conclusions, since they can actually see the spatial data she collects.

"Raw data is often too complex, it needs to be synthesized into something anyone can understand and used as evidence for developing civic change."

Williams is also harnessing data on an international level. In Nairobi, Kenya, her Digital Matatus project is tracking public buses (called matatus) through mobile apps for the first time. Commuters in developed countries might take for granted knowing when the next subway will screech into the station. In developing countries, it's tougher. "People tended to know their own routes but not others. There were no maps of the overall system, making it hard to use," Williams says.

Williams is working with the University of Nairobi, Columbia University's Center for Sustainable Urban Development, and Groupshot, a technology consulting firm, to collect and standardize transit data for matatus via cell phone app. Thanks to this work, the data will be publicly accessible for the first time. And it has sparked the development of mobile phone apps in Nairobi that help residents plan matatu trips. The team has also released the city's first full citywide bus map, with plans to launch similar maps in other cities. The visual map has filled an essential need. Proof? The map has gone viral online.

— KARA BASKIN

ABOVE Sarah Williams uses data, maps, and mobile technologies to develop interactive communications strategies that bring urban policy issues to broader audiences.

PHOTO: LEN RUBENSTEIN

Charging Ahead

A New Method for Wireless Power Transfer

LEFT John Joannopoulos and a colleague pioneer the early work for wireless cell phone charging.

PHOTO: LEN RUBENSTEIN

ONE MORNING, Marin Soljačić walked into the office of fellow MIT professor John Joannopoulos. Soljačić was weary: his wife had forgotten to charge her cell phone, and it had buzzed them awake. Again.

"Can't this thing charge itself?" he asked Joannopoulos. The two, both MIT physicists, immediately began sketching ideas for a wireless charging solution on the blackboard.

"That was the beginning," says Joannopoulos, Francis Wright Davis Professor of Physics and director, Institute for Soldier Nanotechnologies. The work led to the founding of WiTricity several years later, a start-up that is now building wireless charging systems for mobile devices, medical devices, and even electric vehicles.

The science behind wireless charging—the almost magical transfer of energy from one entity to another without wires—has been understood since the days of Michael Faraday. In 1831, Faraday showed that an oscillating electric current in one coil of wire creates a magnetic field that induces current in a nearby separate coil of wire. This principle of magnetic induction is used today to charge electronic toothbrushes, which sit atop a charging platform, close enough to be within range of the tiny magnetic field.

The MIT physics professors wanted to do one better. They wanted wireless charging at a distance, so Soljačić's wife's phone can charge itself even if she abandons it on the kitchen table for the night, a demand shared by many battery-powered mobile device owners.

To meet this goal Soljačić suggested that they build on the concept of coupled resonators. Resonators behave a bit like the opera singer and the exploding wine glass. The singer projects a note into a room full of wine glasses filled to varying levels. The glass that oscillates with the same resonant frequency as the note will begin to vibrate. As the singing continues, energy transfers to the glass until—crash!

Magnetic field resonators exchange energy similarly, though via a magnetic field rather than airwaves. Since coupled resonators oscillate at the same frequency, they transfer energy back and forth very efficiently. They also work at a distance, even at the weak outer reaches of the magnetic field. "The idea is not amazing to physicists," says Joannopoulos. "What was new was figuring how to make a practical magnetic field resonator." Aristeidis Karalis, then a graduate student and now a research scientist in the Research Laboratory of Electronics at MIT, joined the team and began making prototypes. The first demonstration of the technology used copper coils tuned to similar resonant frequencies. They wirelessly lit a 60-watt light bulb nearly seven feet away.

Joannopoulos, along with Soljačić and others in the department, is now focused on harnessing another well-known principle of physics to meet an emerging need for novel energy sources. The goal is to create thermal photovoltaics that resemble solar panels but generate electricity from heat rather than sunlight. The concept is based on the fact that objects, when heated to high temperatures, glow. "That means light is being emitted," says Joannopoulos. "But the idea is to change how that light is emitted, make it more efficient, and then use that light instead of sunlight to create an electric current."

"If they succeed, and early prototypes suggest they might, one possible application could be the creation of a battery with a 20-year lifespan."

The trick? Building a practical solution. If they succeed, and early prototypes suggest they might, one possible application could be the creation of a battery with a 20-year lifespan.

— ELIZABETH DOUGHERTY

Online Database for Imagining New Materials

WHEN GERBRAND CEDER was studying metallurgy in his native Belgium, it struck him that materials science still had a hit-or-miss quality—like ancient smiths accidentally creating bronze by melding malleable copper and brittle tin. Wouldn't it be possible, he wondered, to use known properties of the material world to virtually mix and match elements to predict useful new materials no one had yet envisioned?

Ceder, the R.P. Simmons Professor of Materials Science and Engineering, now describes his youthful notion as a bit naive. Yet his vision is almost exactly replicated in the Materials Project (www.materialsproject.org), originally called the materials genome because it aimed to do for materials what mapping the human genome did for medicine. Since 2011, Ceder's freely available online database has allowed engineers and researchers to poke around like kids in a candy shop for as-yet-unimagined new materials to make, for example, a better solar cell, drug delivery system, or battery. "We have calculated the basic properties—crystal structure, strength, conductivity, density, energy, stability, corrosion, and so on—of nearly all of the approximately 35,000 inorganic materials in nature and another few thousand that exist only in theory," Ceder says.

"It is really up to the creativity of scientists to figure out what new materials can be developed from it. Think of it as a LEGO kit," he says, from which everything from fuel cells to computer chips can be fashioned.

Ceder's fledgling idea for a computer-aided database emerged from a 2005 meeting with Procter & Gamble, which wanted to find a better cathode material for alkaline batteries. Would it be possible, executives asked, to computationally screen all known compounds? "In principle, you can compute almost anything," says Ceder, who earned a PhD in computational materials science. With $1 million in seed funding and access to P&G supercomputers, the Alkaline Project screened 130,000 real and hypothetical compounds and generated a list of candidate materials. Ceder is energized by the fact that hundreds of research professionals consult the Materials Project's web site every day for ways to bypass the frustrating and inefficient guesswork involved with designing a new material. With access to supercomputing clusters at the Lawrence Berkeley National Laboratory in California, MIT engineers use quantum mechanical models that simulate how materials behave in nature to virtually test thousands of materials at a time. "People have reported that a few minutes on the site saved them weeks or months of hands-on experiments," Ceder says.

In today's fast-paced manufacturing environment, timing is critical. Ceder hopes to not only design materials faster, but also to speed them from lab to marketplace. "The faster new materials can be commercialized," he says, "the faster they can be applied to technologically relevant solutions to the urgent challenges of a warming, increasingly crowded planet." — DEBORAH HALBER

ABOVE Gerbrand Ceder's ongoing Materials Project aims to do for materials what mapping the human genome did for medicine.

PHOTO ILLUSTRATION: MARC LONGWOOD

The Second Machine Age

The future is nearly here. "Technologies that used to seem like science fiction are becoming everyday reality," write the co-authors of *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies* (New York: W.W. Norton, 2014). In their *New York Times* best seller, Erik Brynjolfsson and Andrew McAfee make the case that technological advances will reshape the global economy just as steam power did beginning in the 18th century.

"As the majority of economic activity becomes digitized, it will be a fundamentally different kind of world. I'm not talking a century from now; it's a world our children will be living in," says Brynjolfsson, the Schussel Family Professor of Management Science at MIT Sloan. When the second machine age really gets rolling, says McAfee, principal scientist at the MIT Center for Digital Business, "people will be freed from want, drudgery and toil—not just us in the rich world, but everywhere."

The authors predict we will soon witness an unprecedented level of integration of machine intelligence into human affairs, from autonomous vehicles and responsive smart homes to robots in hotels and hospitals, and even to creative services such as writing. Unimaginable opportunities for innovation will transform virtually all sectors of the economy.

"The second machine age will wire up all geeks in the world to each other, and to the sum total of the world's data," says McAfee. "In fact, in the next decade, the majority of the world's people will be networked with a device we know as a computer, and I have a happy enough view of human nature to think it's a good development."

Computers and other digital technologies that seemed for decades laughably bad at such tasks as interacting with humans suddenly began improving over time, the authors say. Exponential growth and diminishing costs of sensors, storage capacity, computing, and connection speeds, and the digitization of content from pretty much everywhere has brought the rapid diffusion of digital information and communication technologies into all spheres of life.

"Machine learning has grown leaps and bounds in just the past few years," says Brynjolfsson. IBM's precisely engineered program Watson astonished in 2011 when it sifted through reams of information to triumph on the game show *Jeopardy*. But new artificial intelligence "not only learns the rules on its own but masters its environment," says McAfee. This will have profound implications for applications involving image, language, and speech recognition. "Teams of humans and machines are coming together to make things they couldn't before," Brynjolfsson says.

But Brynjolfsson and McAfee note that while a digital, networked economy will yield unanticipated paths for creating value and boosting productivity, it can also bring immense job loss and economic disenfranchisement. The web-based photo-sharing platform Instagram, created by 14 people, approached a $1 billion valuation nearly overnight. Almost as quickly, the legacy photography company Kodak, employer of 145,000, collapsed. A tech skills-biased economy dramatically generates winners and losers.

"Ultimately, it's a much bigger pie, with more wealth, and less need for work," says Brynjolfsson. "If that isn't good news, shame on us." To help ensure that as many people as possible share the bounty of this new economy, Brynjolfsson and McAfee have recently launched the MIT Initiative on the Digital Economy, an effort to train the Institute's multidisciplinary talent on problems and policies including productivity, employment and inequality, big data, and the impact of technology on political mobilization. "I'm a mindful optimist," says Brynjolfsson. "If we make an effort to reinvent our institutions, it will turn out well."

— LEDA ZIMMERMAN

ABOVE In their *New York Times* best seller, Andrew McAfee (left) and Erik Brynjolfsson say technological advances will reshape the global economy.

PHOTO ILLUSTRATION: KEN RICHARDSON

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EXCERPT: Chapter one of The Second Machine Age

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‘Cyber Hero’

Supporting Next Generation of Innovators

GROWING UP IN HIS NATIVE PAKISTAN, Ashar Aziz ’81 idolized American inventors he read about. “Thomas Edison, Alexander Graham Bell—even fictional characters like Tony Stark,” he says, referring to the billionaire alter ego of Marvel Comics’ *Iron Man*. “They motivated me, even though they were not part of my environment growing up.” When he was 15, Aziz tried to patent a heating apparatus he’d invented that used magnetic induction, and called information to find the number for the patent office, only to find out it didn’t exist in Pakistan. “It dawned on me that maybe I was in the wrong country,” he laughs.

Aziz persevered, moving to Turkey to study computer engineering and applying twice to transfer to MIT before he was accepted. Even then he wouldn’t have been able to attend had he not received a scholarship. Now sitting in the lobby of MIT’s Koch Institute during a recent visit to campus, he bears a passing resemblance to Tony Stark, with a dark suit and fashionably long hair. He has the billionaire thing covered too; in September 2013, Aziz’s company FireEye went public, and within six months shares had quadrupled in value.

Before he took FireEye public, Aziz spent a decade fighting evildoers in the shadows in the high-stakes world of cybersecurity. FireEye’s technology helped defend companies and countries against hostile network attacks—a phenomenon that has achieved new visibility this past year with cyber-assaults on Home Depot, JPMorgan Chase, and Sony Pictures. Even the US Central Command saw its Twitter account hijacked in January.

> **“Our goal is to take this defensive architecture and make it available even to the smallest organization.”**

“I effectively predicted this 10 years ago, and for a long time, people did not believe me or think this was a problem worth solving,” says Aziz. “I’m glad now I made the time, effort, and investment to develop the architecture to defend against these attacks.” Countries have been launching salvos against companies for years in order to acquire trade secrets and private information of customers.

Most software designed to protect against such attacks works the same way—by developing digital signatures of attackers and blocking them. “It’s like in the old days, you had Bonnie and Clyde robbing banks, and there were wanted posters everywhere with pictures of the bad guys, and eventually they were caught,” says Aziz. These days, however, the most sophisticated attackers are polymorphic, meaning they change the way they look over time.

“It’s as if Mystique is your bank robber,” says Aziz, in another Marvel Comics allusion to the X-Men villain who can change her shape to match any form. “Having a picture is not going to work.” Instead, FireEye uses a different technique, cloning a network environment and allowing an attacker to infiltrate it, and then observing what it does; if it starts attacking the system, the attacker is blocked before it is allowed into the main network.

“The real trick is to do this at speeds of gigabytes a second, in order to work for large banks and oil companies that have hundreds of attacks coming in,” says Aziz. “You have to find the needle in the haystack, and not come up with false alerts in the process.” Going public has given the company the financing to extend its software globally to a broader range of clients. “Our goal is to take this defensive architecture and make it available even to the smallest organization.”

Even before his company went public, Aziz returned the favor that allowed him to attend MIT by establishing two scholarship funds for incoming students, the Ashar Aziz Mens and Manus Scholarship Fund and the Ashar Aziz (1981) Presidential Fellowship Fund. “MIT gave me a generous gift to come to school here, and I felt if at some point in my life I could repay that debt of gratitude, I would do that,” he says. “My hope is that some of these students will do really well one day and they will return the favor and carry on the tradition and it will make a real difference in other people’s lives.”

— MICHAEL BLANDING

ABOVE Ashar Aziz ’81 founded FireEye, whose technology helps defend companies and countries against hostile network attacks.

PHOTO: KEN RICHARDSON

Engineering to Improve Health Care

YOU'RE SICK AND YOU'RE SCARED. So you visit the doctor—who has 15 minutes to spare. You want more answers, but there just isn't enough time.

Sound familiar? Health care engineer Andrea Ippolito SDM '12, ESD '17 thinks so, too. She uses engineering to tackle large-scale logistical problems, like making it easier for patients to secure doctor's appointments.

"My goal is to energize the health-tech ecosystem through engineering. I want to change the way we architect our health care, and there's a hunger for improvement," she says.

Ippolito is an innovator who is working to improve health care through engineering, systems design, and entrepreneurship. At MIT, she's served as a co-director of MIT Hacking Medicine, where the team has held over 20 hackathons to crack medical problems like these across the world. Her own start-up, Smart Scheduling, emerged from a Hacking Medicine event. Smart Scheduling now has paired with athenahealth to develop software that takes the guesswork out of patient scheduling. It tracks patients to remind them of appointments and predicts future scheduling behavior, maximizing a busy doctor's time.

Today, it's a struggle for patients and physicians alike. "The current payment delivery model for doctors is fee-for-service," she explains. "Even though doctors are trying their hardest, volume has to be the focus in order to keep their practice up and running. It's not patient-centric." Hence the hurried, dreaded 15-minute appointment.

"Right now, it can be frustrating for patients to get quick access to an appointment, or often patients experience long wait times. Our goal at Smart Scheduling is to find holes in the clinician's schedule and schedule patients close to cancellations, so that the clinician can see someone else who needs care that day," she says. "Ultimately, it's about providing that really good same-day and next-day access that every patient wants."

To that end, Ippolito is also exploring ways to capitalize on preventative medicine, so patients don't need to visit the doctor so much in the first place. She's worked closely with the U.S. military to help design a telehealth system for service members coping with post-traumatic stress disorder. The system enables homebound patients to consult with a doctor remotely. Sessions usually last five minutes. They provide reassurance to patients—and extra bandwidth for doctors.

Thanks to Ippolito's innovative approach, she recently was named by the White House and the General Services Administration as a Presidential Innovation Fellow. This year, she's harnessing that creativity once again, working with the Department of Veterans Affairs in Washington, DC. The year-long program pairs external innovators with government agencies to spearhead special projects.

"The Presidential Innovation Fellows are trying to infuse the VA with the same energy you see outside government to fuel the development of modern, better products for veterans," she says.

"My goal is to energize the health-tech ecosystem through engineering. I want to change the way we architect our health care, and there's a hunger for improvement."

That's where she comes in: Ippolito is developing an Innovator's Network wherein VA employees from different disciplines and backgrounds will collaborate to solve new problems, like designing ways for wheelchair-bound patients to reach light switches.

"This challenge is just like a hackathon," she says. "Right now the VA's tools are all there. The plane parts are all in the hangar. It's all about someone coming in and asking, 'Why isn't this possible?'"

Thanks to Ippolito's work, it is.

— KARA BASKIN

LEFT Andrea Ippolito uses engineering to tackle large-scale logistical problems, like making it easier for patients to secure doctor's appointments.

PHOTO: KEN RICHARDSON

Microbiome Research

A New Frontier in Medicine

WHEN CLINICAL RESEARCHERS in a Boston hospital were looking for a better way to diagnose inflammatory bowel disease (IBD) in children, Neil Rasmussen '76 got involved. He helped fund a project to look for diagnostic clues in the microbiome, the complex ecosystem of microbes that lives inside the human body and supports human health. MIT biological engineer Eric Alm, the Karl Van Tassel Career Development Associate Professor, was already involved, developing a statistical model that collects stool samples from patients, analyzes the genomes of the microbes present, and recognizes differences from healthy samples.

Rasmussen immediately recognized the value of connecting clinicians to engineers. "MIT was an obvious nexus for this, but instead most research was happening in isolated pockets," he says. "I saw huge value in trying to glue that together, to create a critical mass and get more creative people collaborating in this emerging field."

Rasmussen took action through a $25 million gift to fund the Center for Microbiome Informatics and Therapeutics, a strategic partnership between MIT and Massachusetts General Hospital (MGH). The Center will sponsor collaborative science between clinicians trying to help their patients, and engineers and scientists who collect and make sense of the volumes of patient data needed to study their conditions.

Ultimately, the Center is committed to understanding the role of the microbiome in human diseases such as obesity, autism, rheumatoid arthritis, multiple sclerosis, and other autoimmune disorders, with an initial focus on IBD. "Many of these diseases seem to have correlations in the microbiome," says Alm, co-director of the Center along with Ramnik Xavier, MD, PhD, chief of gastroenterology at MGH. "If we find correlations, then we may be able to develop diagnostics, and in some cases those correlations might give us ideas on how to develop therapeutics to treat disease."

Finding those correlations is a Big Data problem, according to Rasmussen. Really big. "Every person's microbiome is unique. It would be one thing if the microbiome was comprised of three kinds of bacteria, but there are thousands," he says. "And the deeper we dig, the more we find."

The first step towards solving this problem is to collect data, lots of it, from lots of patients. In studying cancer, researchers have learned that new drugs that target specific biological functions often work extremely well for a very small subset of patients. Finding those patients requires large numbers of participants in clinical trials and the analysis of reams of data to determine which patients benefit. This approach is also expected to be useful for diseases rooted in the microbiome.

"It would be one thing if the microbiome was comprised of three kinds of bacteria, but there are thousands. And the deeper we dig, the more we find."

Microbiome research adds to that complexity because it involves not only analysis of human genomes, but also the genomes of the myriad microbes that support human biology, and the interactions those microbes are having with the human immune system and metabolism. Sequencing and informatics tools have advanced to the point where this work is feasible, says Rasmussen, who is a non-voting member of the Center's steering committee. What is needed now is high-quality data.

As a first step, the Center is engaging with clinical researchers who are studying IBD to help them develop standards defining what data to collect and how best to collect it. Such standards, the first application of Rasmussen's "glue," will allow researchers to make the most of the valuable samples collected from patients so that, together, the entire ecosystem of microbiome researchers can learn as much as possible from it.

— ELIZABETH DOUGHERTY

ABOVE Neil Rasmussen took action through a $25 million gift to fund the Center for Microbiome Informatics and Therapeutics.

PHOTO: LEN RUBENSTEIN

READ MORE

Your microbiome "tree" spectrum.mit.edu/webextras


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◀ Cambridge, Massachusetts

Sixty of the Institute's top fundraising volunteers came to campus last fall for the annual meeting of the Corporation Development Committee (CDC). Over dinner, John Reed, Provost Martin Schmidt, and Chancellor Cynthia Barnhart addressed the group about the powerful impact of innovation, education, and research. The annual Marshall B. Dalton Award for outstanding service to MIT was presented to John M. Begg '78 during the program. Accepting the award on his behalf was his son, Nikolai Begg '09, SM '11, PhD '14.

1. Perry '85, SM '87 and Karen Ha '85, SM '87; Anne Street '69, SM '72; Judy Cole; Charlene '79 and Derry '75 Kabcenell
2. Anne Lowell, Claude Brenner '47, SM '48, and Doug Bailey '72, SM '74, ME '75
3. Lois '71 and Jim Champy '63, SM '65; Bob Johnson '63; and Carmen Thain '78
4. Nikolai Begg '09, SM '11, PhD '14; Claude Gerstle '68, the 2013 Dalton Award recipient; and John Reed '61, SM '65
5. Robert Pinto '68, SM '71, EE '73; Cyril Draffin '72, SM '73; and Haejin Baek '86

PHOTOS: SUZI CAMARATA


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Menlo Park, California ▶

Nearly 50 MIT alumni, parents, and friends gathered recently at the Quadrus Conference Center for the second in a series of MIT West Coast Technology Breakfasts, where participants learned about topics at the forefront of today's technology. Conor Madigan SM '02, PhD '06 and Professor Vladimir Bulović, cofounders of Kateeva, a driver of new advances in organic light-emitting diode production technology, discussed the role of nanotechnology in the company's founding. Bulović, associate dean for innovation in the School of Engineering, also spoke about how nanotechnology will enable future innovations at MIT and around the globe.

1. Sumer Johal '96, MNG '96 and Ray Stata '57, SM '58
2. John Chisholm '75, SM '76, and Elda Chisholm ('49)
3. Conor Madigan SM '02, PhD '06; Ralph Scala; Ray Rothrock SM '78; Vladimir Bulović
4. Hans Robertson '99, MNG '03
5. Michelle Chang '94 GM

PHOTOS: BRUCE COOK


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◀ Hong Kong

The MIT Alumni Association, in partnership with the MIT Club of Hong Kong, recently hosted a reception at the Conrad Hilton Hotel. President L. Rafael Reif met with 90 members of the MIT Hong Kong community and participated in a fireside chat with Marjorie Yang '74 and Martin Tang SM '72. The President addressed priorities and vision for the future of MIT, and then the panel answered questions from the group.

1. Barrie Zesiger HM; Christine Reif; Corporation Chairman Bob Millard '73; Julian Lee '97, past president of MIT Club of Hong Kong; and Therese Vien SM '85, president of MIT Club of France
2. President L. Rafael Reif
3. Helen Meng '89, SM '91, PhD '95
4. President L. Rafael Reif, with fireside chat participants Marjorie Yang '74 and Martin Tang SM '72

PHOTOS: BRIAN CHING; DEREK YUNG

The Student Experience

ALAN '73 AND TERRI SPOON believe MIT students will build the future of online education, inventing the tools and technologies of tomorrow.

"We believe that MIT students will be the most creative and liberated innovators of how we teach online," says Alan. "Students are already deeply immersed in the potential benefits of digital interactive education. They're not daunted by the risks of trying something new; they're not bounded by research commitments or conventional methods of instruction."

That's why the couple recently established two funds to support student involvement in the development of MITx, the Institute's approach to the massive open online courses (MOOCs) that are revolutionizing education across the globe. One fund will focus on the MITx Fellows Program, in which students and postdoctoral associates work with MITx leaders to develop course content; the other will help students produce the course videos key to the online experience.

"We thought this gift would be a great way for MIT to get a jump-start on the most innovative possible approaches to effective online education," says Alan, a general partner emeritus at Polaris Venture Partners and longtime member of the MIT Corporation. He also serves on several MIT committees and on the board of edX, the non-profit organization that offers MITx and other online courses to the world. A former architect and development officer, Terri currently works on photography and volunteer projects, including service as an overseer at Boston's Museum of Fine Arts and the DeCordova Sculpture Park and Museum in Lincoln, Massachusetts. She earned a BA in human environment and design from Michigan State University.

"In effect, we're providing start-up funds for students to develop modules of learning," says Alan, who believes that students will design and program unexpected breakthroughs on how best to teach a concept online. For example, they might conceive novel ways of visualizing ideas that are hard to demonstrate in a textbook or at the front of a lecture hall. "The students will invent dramatic insights. They already are."

The couple is also passionate about another student initiative that they founded at MIT, the Community Catalyst Leadership Program, which helps undergraduates become better leaders by matching them with alumni mentors.

"We think MIT students can and should be among the very best leaders in the world," Alan says, adding that hundreds of MIT students already have completed the program. "They come in with dazzling enthusiasm, and they come out shining even brighter." — ELIZABETH THOMSON

LEFT Alan and Terri Spoon believe MIT students will be the future of online education. PHOTO: KEN RICHARDSON

Giving Across Generations

"WHAT'S EXCITING ABOUT ESTABLISHING THE SCHOLARSHIP is it will help individual students and make a real impact in their lives," says Mike Evans '00, who received a scholarship when he was a student and knows firsthand how it can change a life.

"I was going to MIT no matter what, but I hadn't realized that I was actually relying on the generosity of an individual to make it possible. As a junior, I had an email exchange with the donor. I decided right then that someday I would create the same opportunity for someone else."

Evans is the cofounder and former chief operating officer of GrubHub, the wildly successful online and mobile platform for restaurant pick-up and delivery orders. GrubHub expanded the take-out food experience far beyond pizza and Chinese food by using technology to connect hungry customers to thousands of restaurants. Evans took GrubHub from an idea to start-up through two mergers and an IPO. Looking back, he says, "The best thing was, by working together, we created something of value for our customers, and created financial stability for local restaurants—20,000 small businesses across the country."

After the completion of the IPO, Evans turned his attention to photography and writing a science fiction novel, and also reengaging with MIT. He served as a judge for the MIT $100K Entrepreneurship Competition and was a featured speaker at Start6, a workshop hosted by MIT's Department of Electrical Engineering and Computer Science for student entrepreneurs and innovators. To underscore his appreciation to MIT, he recently made a gift for an endowed scholarship.

"I'm hoping to create an opportunity for someone that might not otherwise be able to go to MIT, who will then go on to do great things with their education. And I hope that one of them might continue the cycle and support the next generation of MIT students."

— LAURIE EVERETT

RIGHT Mike Evans is cofounder and former COO of GrubHub, the wildly successful online and mobile platform for restaurant pick-up and delivery. PHOTO: KEN RICHARDSON

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