Massachusetts Institute of Technology
Winter 2018

Spectrum

PLUS

INTRODUCING THE MIT INTELLIGENCE QUEST
P. 35

PATHWAYS → POLICY

Ernest J. Moniz poses with a student following his delivery of the fall 2017 Compton Lecture at MIT. Now the Cecil and Ida Green Professor of Physics and Engineering Systems emeritus and special advisor to the MIT President, Moniz served as US Secretary of Energy from 2013 to 2017. In that role, he placed energy science and technology innovation at the center of the global response to climate change and negotiated the Iran nuclear agreement alongside the Secretary of State. Moniz joined MIT's faculty in 1973 and was founding director of the MIT Energy Initiative (MITEI). Under his leadership, MITEI began producing its series of in-depth studies providing technically grounded analysis to energy leaders and policy makers on topics such as nuclear power, coal, the electric grid, and natural gas.

PHOTO: JAKE BELCHER

Wide Angle

Subjects

SPECIAL SECTION

Pathways to Policy

Breakthroughs and Insights

Inside the MIT Campaign for a Better World

FRONT COVER
Graduate students from all five MIT schools are making policy connections (see page 18). Clockwise from left: Daniel Gilford, Mayara Felix, Samantha Zyontz, Abigail Regitsky, Reed Jordan.

PHOTO: M. SCOTT BRAUER

BACK COVER
The MIT List Visual Arts Center's exhibition *Before Projection: Video Sculpture 1974–1995* runs February 8–April 15, 2018. Pictured, from that exhibition: Nam June Paik's *Charlotte Moorman II*, 1995. Courtesy Rose Art Museum, Brandeis University; Hays Acquisition Fund. Visit listart.mit.edu.

PHOTO: ©NAM JUNE PAIK ESTATE

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From Research to Policy

When engineers describe how an idea becomes a product, we say that it moves from "lab to market." It's a clean, concise way to capture what in reality can be a messy, arduous, and unpredictable path to success.

Melissa Nobles, Kenan Sahin Dean of MIT's School of Humanities, Arts, and Social Sciences, and former head of our Department of Political Science, sees a compelling parallel in the work of MIT's social scientists whose ideas move from "research to policy." As social scientists conduct research to inform policy, they iterate. They prototype. They optimize. And in the end—like everyone at MIT—they aim to make a positive impact in the world.

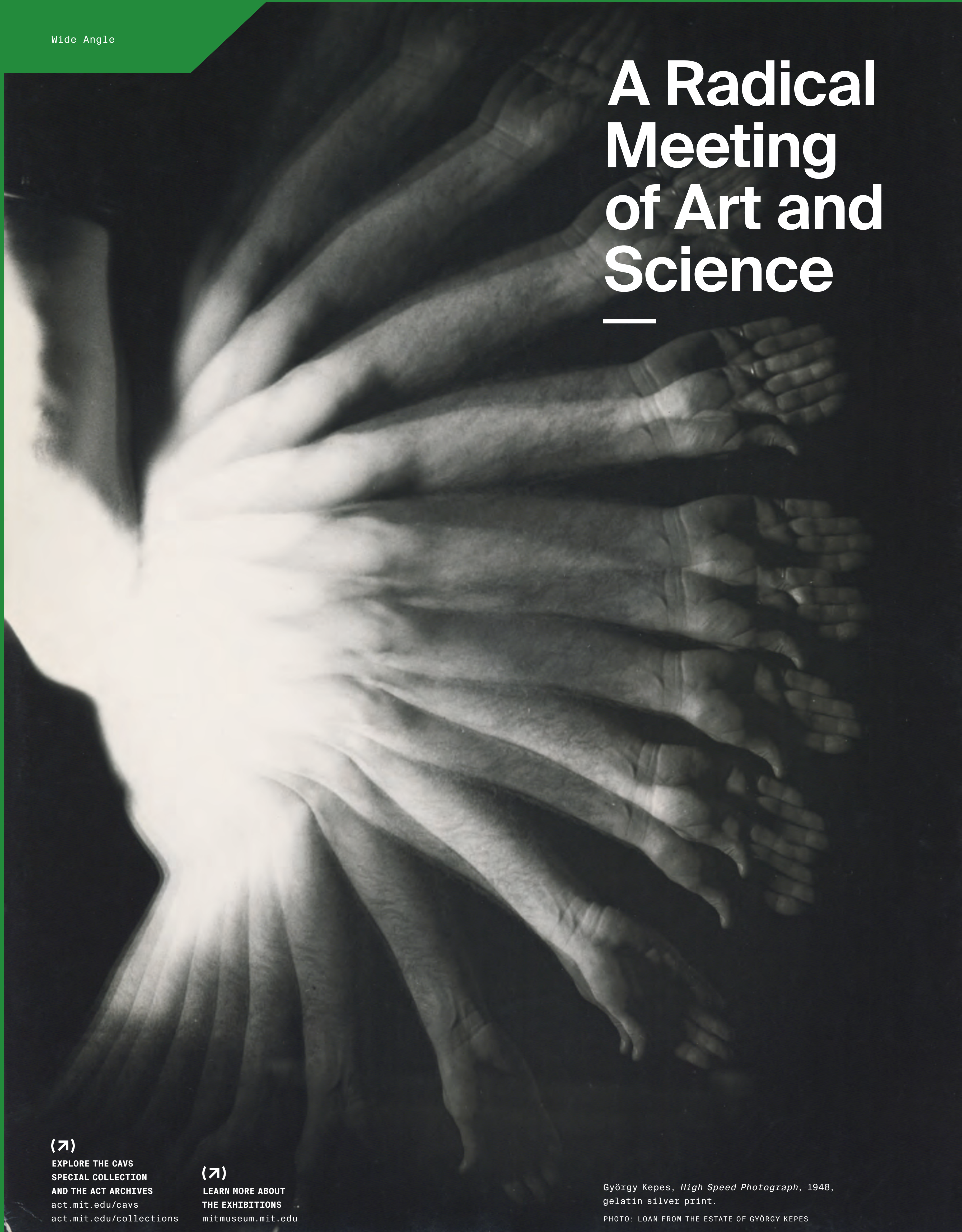
Across campus, in all five schools, MIT's faculty, researchers, and students are grappling with tough policy questions that affect the entire planet. From artificial intelligence and cybersecurity, to health care and energy efficiency, we're applying the Institute's "mens et manus" ethos to assessing existing policies and advancing research that informs new ones, for the betterment of humankind.

Take, for instance, MIT's Abdul Latif Jameel Poverty Action Lab (J-PAL), a network of 158 affiliated professors from 49 universities working to reduce global poverty. To determine which poverty programs are actually making a difference, in the US and around the world, J-PAL tests them through the gold standard of double-blind randomized evaluations. Just as a biologist assesses the efficacy of a new vaccine, J-PAL's researchers experiment, gather evidence, evaluate the results, and optimize the policy—MIT at its finest.

As you'll read in this issue of *Spectrum*, J-PAL has launched an initiative to partner with governments to design and evaluate policies more broadly. From improving education in Zambia to fighting crime in Brazil, J-PAL is now applying its trademark rigor to complex policy challenges beyond global poverty—and in the process, showing the world that optimizing for impact is how we do just about everything here at MIT.

L. RAFAEL REIF

LEARN MORE
betterworld.mit.edu



A Radical Meeting of Art and Science

Half a century ago, György Kepes (1906–2001) established the Center for Advanced Visual Studies (CAVS) at MIT as a lab for interdisciplinary art practice and research. As a direct result, more than 200 contemporary artists would form an affiliation with MIT in the subsequent decades.

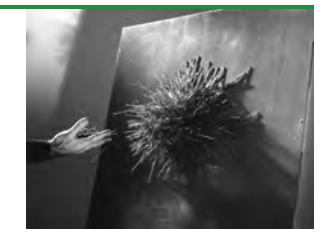
The Hungarian-born Kepes first came to MIT in the years following World War II, at a moment when the Institute was reimagining its curriculum and cultural role in peacetime. At that time, Kepes was best known as a mentee of Bauhaus legend László Moholy-Nagy and as the author of the influential design book *Language of Vision*. According to MIT Museum curator Gary Van Zante, Kepes "immediately assimilated into MIT culture: scientific research became hugely influential to him." In his own art, and in his curating and theoretical writing, Kepes "looked at scientific imagery and traditional photographic imagery with equal interest, in a way that was pretty radical," Van Zante says. The founding of CAVS fulfilled Kepes's vision of bringing cutting-edge artists—who spanned many of the disciplines he himself practiced, including painting, photography, stage design, graphic design, and film—into technologically adventurous collaboration with MIT's scientists and engineers.

To mark the 50th anniversary of CAVS, the MIT Museum has organized two exhibitions of Kepes's photography, including many works never before displayed to the public, some newly printed from original, vintage negatives. A look at his pre-MIT work closes March 5. Photographs from Kepes's MIT years will be on view beginning March 22, highlighting his experimentation with the principles and techniques of image-making and the range of scientific imagery that influenced his work. Selected works from the history of CAVS—which is now part of the MIT Program in Art, Culture and Technology (ACT)—can also be seen at the MIT Museum starting February 15, as well as in a new online archive launched by ACT last fall. ACT will also sponsor a series of campus-wide events and exhibits in honor of the anniversary this spring.

1937: Kepes emigrates to the US and begins teaching at the New Bauhaus in Chicago.

1946: Kepes accepts an invitation from MIT's School of Architecture and Planning to teach visual design.

1967: Kepes establishes CAVS, which moves into a renovated Building W11 at 40 Massachusetts Avenue.



1968: Pictured: CAVS fellow Vassilakis Takis's electromagnetic sculpture *Antigravity*.

PHOTO: NICHAN BICHAJIAN

1971–73: The *Charles River Project*, an early CAVS collaboration, exhibits site-specific proposals intended to provide urban residents with opportunities for interaction with and contemplation of their environment.

1972: Pictured: sketch of sculpture over photograph for proposed environmental sculpture *Pigeon House*, by CAVS fellows Maryanne Amacher, Luis Frangella, and Keiko Prince.

1974: Otto Piene succeeds Kepes as director and will hold the position for 20 years. He intensifies the CAVS commitment to "art at the civic scale" while solidifying his place as a leading figure in kinetic and technology-based art (pictured: *Olympic Rainbow*, Munich Olympics, 1972).

PHOTO: MIRA CANTOR

1977: Germany's "documenta 6" exhibition commissions from CAVS one of its most ambitious undertakings: *Centerbeam*, a massive kinetic sculpture remounted one year later on the National Mall.

PHOTO: ELIZABETH GOLDRING

1989: By the end of his two decades at CAVS, conceptual artist Lowry Burgess has created the first artistic payload to be carried into outer space by NASA.

1989: The MIT Visual Arts Program (VAP) is founded within the Department of Architecture by Professor Ed Levine to provide undergraduate and graduate instruction in the arts.

1994: VAP faculty member Krzysztof Wodiczko becomes CAVS director. He is instrumental in its shift toward questions of geopolitics, identity, and environmental citizenship. (Pictured: Wodiczko's *Alien Staff*, 1995.)

1996: Stephen Benton '63, inventor of the rainbow hologram, assumes the directorship of CAVS. Following Benton's death, Wodiczko will resume the role.

2005: Ute Meta Bauer becomes the director of VAP, which grows under her stewardship.

2009: VAP and CAVS merge into the MIT Program in Art, Culture and Technology (ACT).

2015: ACT Professor Emeritus Joan Jonas is the US representative at the Venice Biennale with a new solo show, *They Come to Us without a Word*, organized by the MIT List Visual Arts Center.

PHOTO: COURTESY OF THE ARTIST

2018: Alongside Jonas and new ACT director Judith Barry, ACT's faculty includes Azra Akšamija PhD '11, Renée Green, and Gediminas Urbonas. Eleven grad students are working toward a Master of Science in Art, Culture and Technology (SMACT) and 103 undergrad and grad students enrolled in ACT courses in Fall 2017.

ALL TIMELINE PHOTOS (EXCEPT JONAS): COURTESY OF CENTER FOR ADVANCED VISUAL STUDIES SPECIAL COLLECTION, MIT PROGRAM IN ART, CULTURE AND TECHNOLOGY

György Kepes, *High Speed Photograph*, 1948, gelatin silver print.

PHOTO: LOAN FROM THE ESTATE OF GYÖRGY KEPES

EXPLORE THE CAVS SPECIAL COLLECTION AND THE ACT ARCHIVES
act.mit.edu/cavs
act.mit.edu/collections

LEARN MORE ABOUT THE EXHIBITIONS
mitmuseum.mit.edu

Space Detectives

A freshman advising seminar investigates clues from the formation of new worlds

TITLE

12.A03 Meteorite from Mars Kills Dog: The Inside Story on Planets

INSTRUCTOR

Tim Grove, Robert R. Shrock Professor of Earth and Planetary Sciences

The curriculum and readings change as new discoveries in planetary science are made, so Grove—who has taught the course since the early 1990s—rarely leads the same discussions year-to-year.

FROM THE CATALOG

Freshmen will recreate planetary formation in the laboratory. Each class looks at the way in which different planets formed and evolved by exploring the clues found in meteorites, moon rocks, and molten lavas (magmas) from within the Earth and Mars. Students survey the variety of magmas present throughout the solar system, including melts that condensed from gas during the formation of the solar system and magmas formed on asteroids. They will discuss theories about the events that led to the formation of Mercury, Venus, Earth, and Mars. In addition to weekly readings and several brief problem sets, there will be hands-on experience with meteorites from the asteroid belt, meteorites that may be samples of Mars (one of them rumored to have killed a dog when it landed in Egypt in 1911), and rocks from the moon. In the lab, students recreate the intensely elevated pressure and temperature conditions achieved in a planet's interior and create their own magma.

Megan Guenther '21: "The course's name piqued my interest, as well as planetary formation and geology."

FORMAT

The class is part of the Freshman Advising Seminar (FAS) program. Grove believes strongly in providing all freshmen the opportunity to **build relationships** with faculty members in their fields of interest. He was a driving force in an initiative to ensure every MIT freshman is assigned a faculty adviser, either through the **FAS program** or one-on-one mentoring.

Grove: "A network of mentors is just about the most important thing that one should get out of a college education. These kids should get to know at least one or two faculty members every year well enough that the professors could write them a letter."

Guenther: "The advising seminars do a great job of breaking down the barrier between professors and students. I love being able to brag that my advisor has an asteroid named after him."

Enrollment is capped at eight freshmen. The seminar is casual—designed as a discussion section that allows active participation. The group meets for two hours every Monday afternoon. Grove brings pizza to each class and begins by asking his students about the past week. He encourages them to unload and vent about difficult tests or problem sets. A **sophomore associate advisor** is also enrolled in the class. This student acts as a peer mentor, encouraging class discussions and helping to answer any questions first-year students have on navigating MIT.

Associate advisor Hannah Michaye Ledford '20: "I like how low-key the class is—and it's nostalgic seeing the freshmen."

Surrounded by shelves of rocks and geologic models, the students study maps of extraterrestrial landscapes and discuss theories about such topics as water on Mars. Each week, students prepare for class with articles that Grove sends out a few days before they meet. The curriculum and readings change as new discoveries in planetary science are made, so Grove—who has taught the course since the early 1990s—rarely leads the same discussions year-to-year.

Grove examines a map of the Martian landscape with students, from left, Kai Masterson, Megan Guenther, Anmol Maini, and Ulyana Piterbarg.

PHOTO: SARAH BASTILLE

CURRICULUM: FALL 2017

WEEK 1: How to use meteorites to date the solar system

WEEK 2: Discuss the formation of chondrites, meteorites made from the earliest particles of the solar system

WEEK 3: Learn about the asteroid belt and the meteorites that come from there

WEEK 4: Study theories for the formation of inner rocky planets

WEEK 5: Discuss the theories for why and how the moon began orbiting the Earth

WEEK 6: Understand what we can infer about Martian planetary history from **Martian meteorites** and the geological formations on Mars

The titular meteorite gets an in-depth investigation this week. (Spoiler alert: After examining news reports and other sources, the class determined the meteorite probably did not, in fact, kill the dog.)

WEEK 7: Explore the geology of the moon

WEEK 8: Learn about **Mercury** from images and information gathered by Mercury Messenger

Grove: "That one I just added since the Mercury Messenger mission brought back all this amazing data. Up until just four or five years ago we didn't know much about Mercury at all."

WEEK 9: Study the formation of **other star systems**

Grove: "We talk about how the hydrogen in your body is 13.2 billion years old and how we're all made of stardust."

WEEK 10: Watch science fiction movies that feature **bad planetary science**

Selections include *Red Planet* (2000) and *Armageddon* (1998).

WEEK 11: **Make magma**

Grove: "I take them into my lab and show them how we melt rocks under all kinds of different conditions. We use these fun and idiosyncratic pieces of equipment that we've built over the years."

—Stephanie McPherson SM '11

PATHWAYS → POLICY

They say knowledge is power, but that's leaving out some crucial steps. Knowledge created at MIT does have the power to change the course of health care, or to protect the health of the planet—but only when it reaches those who are best positioned to use it. That's why our researchers find avenues for collaboration with governments, businesses, and other organizations that can translate their findings into widespread action. MIT's experts provide decision makers with the ideas, information, and tools they need; evaluate the outcomes of existing policies; model uncertain consequences; and enrich public dialogue on issues that may shape our society. And every step of the way, we advocate for the advancement of education and research—so that those charged with steering the world will always have new knowledge to guide them.

PHOTO OF STAIRCASE IN MIT BUILDING E15: CC BY-SA JEANBAPTISTEPARIS

Better Governing through Science

A new initiative from the Jameel Poverty Action Lab helps policy makers worldwide embrace the value of evidence

Governments have a reach into the lives of the poor that is unequaled by any nonprofit aid organization. That's why MIT's Abdul Latif Jameel Poverty Action Lab (J-PAL) launched its Government Partnership Initiative—to team up with governments to advance policies that have been scientifically proven to help people living in poverty.

"Developing country governments are by far the biggest funders of poverty relief in the world. So, the biggest lever you can have in reducing poverty is getting that money spent better," says Rachel Glennerster, who was J-PAL's executive director until January of this year and is now on leave serving as chief economist for Britain's aid agency, the UK Department for International Development.

J-PAL's Government Partnership Initiative (GPI) helps governments evaluate policies, scale up successful ones, and build an internal culture of evidence-informed decision making. A competitive fund, GPI supports the work of J-PAL, which was founded in MIT's Department of Economics in 2003 "to reduce poverty by ensuring that policy is informed by scientific evidence." Since then, J-PAL's research network has conducted more than 800 randomized evaluations measuring the impact of social programs in 80 countries.

Mahuba Hazemba, senior officer of the Zambia Ministry of General Education, helps a student in Gujarat, India. The goal of his visit there with J-PAL staff was to learn about evidence-informed remedial education.

PHOTO: COURTESY OF J-PAL

"The 'in thing' in development is to think about ways to bypass government and deal directly with people or via other non-state actors," says Iqbal Dhaliwal, J-PAL's new executive director and GPI co-chair. (GPI's other co-chair is J-PAL Director Abhijit Banerjee, the Ford Foundation International Professor of Economics at MIT.) "We have realized in the past 12 to 13 years at J-PAL that whether you like working with a particular government or not, there's no alternative if you want to make big changes."

Launched in 2015, GPI has so far awarded $1.8 million for 24 partnerships in 13 countries, spanning a wide range of programmatic areas—from tackling a court backlog in Mexico to implementing educational reforms in Zambia and even creating a culture of evidence-based policy making in one of the major states of India. Average grants range from around $50,000 for a pilot to $90,000 for a full project.

Why would governments with budgets in the billions need such small sums?

Dhaliwal says that it's because most government dollars are tied to specific programs, making it surprisingly difficult to divert money to new initiatives.

"We've realized that small amounts of money, given for the right purpose to the right department, can have a big effect," he says. "Small projects can change the decision-making process, then change the direction of the bigger ship." Once the effectiveness of a new program is clear, governments can use their own resources to expand benefits to the whole population.

Low cost, big impact

"The research is demand-driven," says J-PAL senior policy manager Claire Walsh, noting that GPI has far more requests for support than it can fulfill. To date, 85 proposals have come in from 27 countries at various levels of government requesting a combined total of $8.4 million.

While GPI often provides less support than requested due to high demand, Walsh says that even low-cost interventions can have a big impact. For example, in Mexico City, GPI provided just $50,000 for an evaluation by a J-PAL-affiliated researcher of the benefits of giving labor court claimants information about success rates of similar cases. The research showed that providing such information increased the use of alternatives (such as mediation) to resolve disputes—significantly reducing the court's nearly four-year backlog. GPI has since approved a grant to scale up the program.

GPI has so far awarded $1.8 million for 24 partnerships—from tackling a court backlog in Mexico to implementing educational reforms in Zambia.

Scaling up successful programs is a central focus of GPI, which also provides funds for the technical assistance governments need to expand pilots or adapt programs already proven to work elsewhere. "You don't always have to do new research, and you can't use research funds to do technical assistance," Glennerster says. "That's the niche GPI is filling."

In Zambia, for example, to improve chronically low learning levels, GPI has been helping educators tailor instruction to the level of the child rather than the level of the curriculum. This approach has been thoroughly tested by J-PAL with partners in India and is known to improve educational outcomes. Nevertheless, implementing the program in Zambia presented unique challenges.

"It's not a pill you can just take off the shelf," says Glennerster, who served as a lead advisor for the Zambia project. Glennerster notes, for example, that the school day, curriculum, and staff capabilities are very different in Zambia than in India. "You need someone who really understands the research to help governments adapt research to their context and sort through practical issues."

GPI funded J-PAL's Africa office to provide the technical assistance Zambia required to adapt the teaching approach to its needs, including developing a model of the program to pilot in 80 schools and conducting an independent assessment of the pilot, which proved successful. Last August the government committed to rolling out the level-teaching program to approximately 1,800 schools over the next three years.

Better decision making

Ultimately, GPI is working to institutionalize a culture of evidence-informed policy making within governments so that nations make better decisions going forward. That is exactly what is happening in Tamil Nadu, India, a state that is home to 78 million people—nearly a quarter the size of the United States population. GPI has teamed up with officials there to help the state meet its commitment to pilot and rigorously evaluate innovations in all its departments and to scale those interventions that are found to be effective.

Tamil Nadu has allotted more than $4 million to the project—an "unprecedented amount" of government support for evidence-based policy, according to Dhaliwal—and GPI is providing ongoing assistance. For example, GPI funded two J-PAL staffers to work directly with the government on its evaluations, including helping the state set up a central data analytics unit to inform its decision making.

Already, Dhaliwal says government officials in Tamil Nadu are internalizing the principles behind J-PAL's method of assessing anti-poverty programs. He recalls a recent meeting he attended at which the head of the civil service, unprompted, pointed out the need to compare outcomes for people who received an intervention with those for a control group who did not. "It's incredible when such senior officials in the government understand so well the underlying science. I got goose bumps," he says.

In 2014, government officials of Tamil Nadu met with J-PAL's Shobhini Mukerji (far right) and Esther Duflo and Iqbal Dhaliwal (right of center) to launch a collaboration increasing the Indian state's use of evidence in policy making.

PHOTO: COURTESY OF GOVERNMENT OF TAMIL NADU

"These projects are changing the culture. Once you change the culture, you don't need J-PAL and MIT to be there," he says. "Hopefully, governments will make more evidence-informed decisions on their own."

—Kathryn M. O'Neill

Vote of Confidence

The nonpartisan MIT Election Data and Science Lab champions the efficiency, integrity, and transparency of the democratic process

In 2000, hanging chads clouded the presidential election between George W. Bush and Al Gore. In 2016, allegations of Russian hacking swirled around Hillary Clinton and Donald Trump. Meanwhile, long lines continue to plague polling stations, possibly alienating voters and overwhelming poll workers. Even in a democracy like the United States, elections can be fraught with controversy.

Not if the MIT Election Data and Science Lab (MEDSL) can help it. Launched in January 2017 and helmed by founder Charles Stewart III, MEDSL hopes to bring greater efficiency to elections through science and community engagement. Housed within MIT's School of Humanities, Arts, and Social Sciences and established with the support of the William and Flora Hewlett Foundation's Madison Initiative, the lab collects and disseminates data about elections, primarily in the US, with a grounding in scientific research.

The initiative comes at a time when US citizens' trust in the election process is more at stake than ever, says Stewart, the Kenan Sahin Distinguished Professor of Political Science at MIT. "Every election has something wrong. We often don't know what it will be, so the academic community and the research base are left trying to respond and scramble.

"After 2016, two new issues have emerged: the 'hacking' of the election process and charges of fraud associated with voter registration. Historically, the academic world responded to these types of new issues very slowly and inefficiently, because no one had flexible resources to move quickly into new fields," Stewart says. "Now, the presence of the lab has given me the opportunity to focus on new issues like these as research topics." He adds, "The hope is that by 2020, we'll have an ongoing research operation so that whatever the problem is, we'll be there to guide both policy making and a public discussion."

To foster this kind of nimbleness, first and foremost, the nonpartisan lab disperses research grants through a New Initiatives Fund. It will award $400,000 over the coming three years to researchers at MIT and beyond studying topics like voucher programs for candidates and the cost of running elections.

In addition, MEDSL has several initiatives building on its core research activities. For example, the lab offers a resource portal for a group crucial to the democratic process: "Election administrators are being better educated and are more likely to want to manage through metrics and the best scientific literature," Stewart notes. "However, there's a chasm between academic resources and practitioners." One way the lab is helping to bridge that gap is by assembling scientific tools to help local officials better manage long lines at polling sites. The Caltech/MIT Voting Technology Project (VTP), which Stewart also co-directs, developed a web-based application focusing on queue theory and protocols to help election officials monitor and improve wait times and allocate proper resources.

"We worked with state and local officials to teach them how to gather data, to see how long waits were, and to identify where problems were. This is how fundamental science and engineering can be then moved into polling places," he says.

MEDSL also helps to connect like-minded individuals and institutions. Stewart is building what he calls an "election science research network" among scholars throughout the country to encourage the sharing of data and analysis. This will launch next winter. Looking ahead, Stewart also plans to convene statisticians, social scientists, and legal experts to discuss the scientific and legal frameworks needed to enforce properly tallied voting.

"One technical issue that has come out of the 2016 election is whether elections are audited after the fact and, if they are, how they are audited. We're planning on hosting a public conference next year to bring together academics, citizens, and the press to educate people about techniques and to puzzle together how to get them adopted by election officials," he says. "We want to review the state of the science and also try to understand what it would take in terms of legal frameworks to respond to cybersecurity concerns and techniques to deal with hacking—this is an area where we could have a real impact."

One of MEDSL's most valuable overarching functions, according to Stewart, is to serve as a data archive and clearinghouse. "A major goal is to make election data available to the general public and not just to the political consultants who charge an arm and a leg to their clients for it."

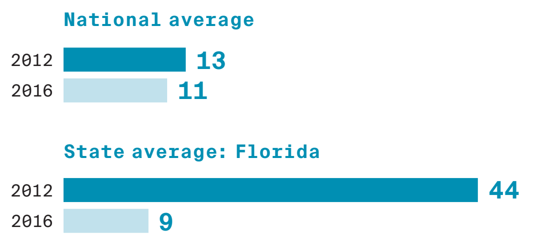
> "A major goal is to make election data available to the general public and not just to the political consultants who charge an arm and a leg to their clients for it," says Stewart.

> The initiative comes at a time when US citizens' trust in the election process is more at stake than ever.

In one timely example of this, MEDSL is working to gather returns at the precinct level from the 2016 election and to publish them in an open-source format, the value of which extends beyond scholarship. "States and localities don't publish election results in a uniform fashion, so just gathering and processing election results is a major service to numerous communities. This data will be the major input into the upcoming round of redistricting that will follow the 2020 election," says Stewart, explaining that open-source redistricting programs "serve as an important check against partisan and incumbent-protection gerrymanders" by allowing members of the general public to put forth their own proposals. "The availability of this data in a public format will allow the civic groups that are trying to draw the public into the process to do their work. It's really impossible to do so without data," Stewart adds. "We're really upping the game."

—Kara Baskin

WAIT TIMES AT POLLING SITES
(in minutes)



The average wait faced by voters dropped nationwide from the 2012 to the 2016 election—and markedly so in states such as Florida that experienced the longest waits in 2012. Stewart believes this improvement can be attributed in part to resources provided to local election officials by MEDSL and VTP, along with other factors such as changes in voting laws.

SOURCE: SURVEY OF THE PERFORMANCE OF AMERICAN ELECTIONS (PI: CHARLES STEWART III)

PHOTO: STUART DARSCH, BOSTON

PHOTO: ©2013 HERO IMAGES INC.

The Final Yard

The International Policy Lab helps faculty ideas take those last critical steps into the corridors of power

Brilliant scientific ideas and ingenious technical solutions can't really change the world if they never escape the laboratory and the pages of scientific journals. At a place such as MIT where innovation is an almost daily occurrence, that can be a frustrating dilemma. The International Policy Lab (IPL) was set up within MIT's Center for International Studies (CIS) to help make the leap from the lab bench or seminar blackboard to the halls of Congress or a decision maker's desk.

"The genesis of IPL was the realization that we had a number of faculty members at MIT whose research was relevant for public policy"—with bearing on such important issues as energy, environmental science, national security, or health and medicine—"but who weren't sure how to engage with the policy community," says Chappell Lawson, associate professor of political science and IPL's faculty director. As he puts it, "Sometimes we fumble the ball on the one-yard line, so that after a massive amount of work on the research side of things, for whatever reason that material doesn't get into the right hands of the right people at the right time. That last piece is often what's missing."

Lawson joined MIT after a stint in government on the staff of the National Security Council in the Clinton Administration, and later took time out to serve in the Obama Administration working on border security issues for the Department of Homeland Security. It was upon returning from that second adventure in Washington that he, along with several other like-minded faculty, recognized that an opportunity to solve this problem was staring them in the face. "An assistant secretary in the federal government is not going to read a 30-page report, but they might take a meeting, listen to a short pitch, or read a one-page memo," he says. What if MIT could help faculty members find the right way to engage with policy makers? About three years ago, Lawson and his colleagues secured funding from CIS, the dean of the School of Humanities, Arts, and Social Sciences, and the Office of the Provost, and began soliciting project proposals from the MIT community.

A good early example of the sort of projects that IPL has come to facilitate came from R. Scott Kemp, associate professor of nuclear science and engineering and director of the MIT Laboratory for Nuclear Security and Policy. Kemp's project concerned the proliferation risks of a new laser enrichment process for uranium.

Many MIT faculty members, such as Jessika Trancik (pictured above presenting her research on energy technologies in Davos, Switzerland), look to the MIT International Policy Lab for assistance in translating their findings into the language of policy.

PHOTO: WORLD ECONOMIC FORUM, 2017

"The reason this was of interest was that there had been a quiet push to license and build a facility in the US, but no government agency had carried out a technical assessment of the nuclear weapons proliferation risk that the technology might bring if it were commercialized," Kemp explains. According to Kemp, neither the Nuclear Regulatory Commission nor Congress chose to examine the problem, meaning "the US was moving forward in blind ignorance of potential risks to international security that this technology might involve. So we took it upon ourselves here at MIT to actually carry out that assessment."

That's where IPL came in. Says Kemp, "IPL not only supported our work and outreach, but also in essence carried out research relative to what the perceived risks were in government, so we understood what was already being taken into account, what was not being taken into account, and then who were the right people to talk to." As it happened, the companies involved with the laser enrichment technology ultimately decided not to pursue it, but IPL was "instrumental in helping us get important technical facts into the hands of the people who needed to make decisions."

> "An assistant secretary in the federal government is not going to read a 30-page report, but they might take a meeting, listen to a short pitch, or read a one-page memo," Lawson says.

Kemp's next IPL project involved a new technical solution for the verification of nuclear warhead dismantlement. He says that IPL helped his group cut through the "not invented here" syndrome that often pervades federal bureaucracy and creates resistance to outsiders' ideas. "We've certainly put them on notice that some of the technology development being done at MIT should be looked at more seriously, and IPL was very instrumental in making that happen," Kemp says.

The IPL has helped MIT faculty reach international policy makers as well. Jessika Trancik, associate professor at the Institute for Data, Systems, and Society (IDSS), engaged IPL resources to respond to an Obama Administration request for a report on her research addressing the feedback between emission reduction policy and technological innovation in clean energy. That report was used by the White House to inform its work in the months leading up to the COP21 Paris Climate Conference in 2015, and referenced by State Department negotiators during the COP. Another of her IPL projects examined methane emissions, their effect on meeting US climate goals, and their relevance to energy policy. IPL has been "an invaluable resource for strategizing about how to translate research results into useful information for policy makers," she says.

Trancik is also co-faculty director of the IPL with Lawson and Noelle Selin, an associate professor affiliated with IDSS and the Department of Earth, Atmospheric and Planetary Sciences. "So now I'm also working with IPL to think about how we can expand our footprint and build on this initial success and amplify that further," Trancik says. "We're brainstorming ways to get different projects and faculty members and researchers to engage with each other to share lessons and build a community around policy research here at MIT."

In addition to using IPL in their own work, faculty participants help to review the project proposals that IPL solicits annually from the MIT community. "The idea is to serve faculty at all five schools, including social scientists and urban planners and MIT Sloan faculty as well as scientists and engineers," Lawson explains, noting different projects call for a range of approaches. "For some, the right strategy might be to meet with people in the executive branch. For others, it might be to meet with people on the Hill, or some combination of the two. And for still others, it might be a much larger audience, like experts who are outside of government or even the informed public who cares about the issue."

Lawson boils down IPL's services to three points: "The first is working with faculty members to define what it is that they want to get out of engaging with the policy community. The second is almost a matchmaking service, connecting faculty members with people in government, the executive branch, legislative staff, think tanks, the media, who are interested in the results of their research and are in a position to make policy that's related to it. And we provide staff support and modest grants to faculty members for engaging in this sort of outreach."

Emphatically a nonpartisan endeavor, IPL does not seek to influence policy on behalf of MIT, but the faculty members it assists often do comment on how specific policies might influence outcomes, based on their research findings. That policy makers are receptive to such input, Lawson observes, is due in part to the Institute's strong reputation. "MIT is not viewed as 'liberal academia,'" he says. "People recognize the value of the science and engineering that's done here. It's an institution that people on both sides of the aisle have great regard for. That offers a real opportunity to connect on technical and scientific issues."

It may have started out as something of an experiment but IPL is flourishing: the number of proposals submitted has

PORTRAITS BY: JUSTIN KNIGHT (KEMP AND TRANCIK), STUART DARSCH, BOSTON (LAWSON)

What was originally conceived as a more or less one-way conduit from MIT to Washington is becoming more of a two-way connection, the beginnings of a symbiosis.

roughly doubled each year. And other unexpected benefits are beginning to appear. Not only are some faculty members building more long-term relationships with policy makers in their fields, but as Lawson notes, "we've seen that their understanding of the policy issues can inform their research. They may choose to work on slightly different topics or work on them in a slightly different way because of the interactions they've had with policy makers." So what was originally conceived as a more or less one-way conduit from MIT to Washington is becoming more of a two-way connection, the beginnings of a symbiosis. Lawson, the former Washington insider turned academic, cites other rewards—"a wonderful feeling from watching MIT professors get more engaged in policy and having policy better informed by science," he says, and "the pleasure of helping to address a major market failure in the American political system."

For faculty members like Kemp, the "translational element" remains paramount. "It's completely inadequate to publish results in a technical journal and expect anyone to pay attention to them," he says. "You have to frame these issues within the incentive structure of the people making decisions, and IPL is good at finding out what that context is. I think it helps MIT have a lot more impact in the world." –Mark Wolverton

Wolverton is a 2016–17 MIT Knight Science Journalism Fellow.

Seminar XXI: Educating US National Security Leaders

It's quite possible that at least some of the decision makers the International Policy Lab (see page 12) seeks to reach are alumni of another program at the Center for International Studies: Seminar XXI. Conceived in 1984 by MIT Raphael Dorman-Helen Starbuck Professor of Political Science Suzanne Berger, Mitzi Wertheim at the Naval Postgraduate School, and retired US Navy Captain Jake W. Stewart, it's a one-of-a-kind educational program for current and future leaders in the US military, foreign policy, and national security fields.

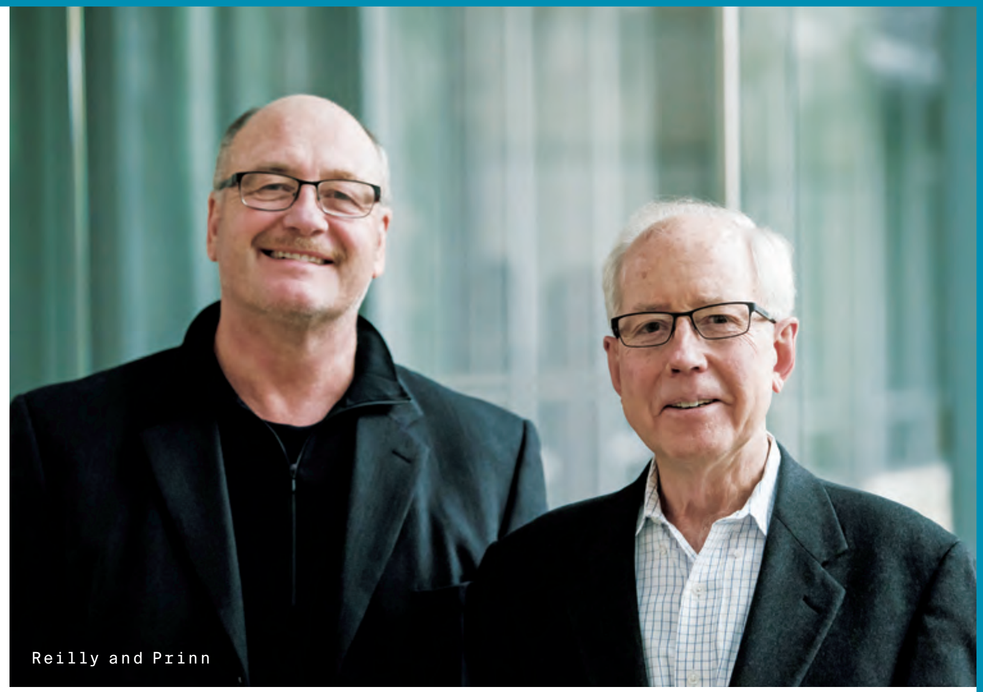
The nine-month, eight-session seminar program adapts and extends material and educational approaches from several graduate-level MIT courses in foreign policy and international studies, aiming to provide participants with "the broad perspectives and analytical skills required to evaluate and formulate effective policy options for the United States," as director Robert Art explains. In a series of intensive, immersive sessions held in downtown DC and nearby Virginia, Seminar XXI not only brings in faculty from MIT but is also able to tap into all the resident expertise of the Beltway, engaging instructors with vast foreign policy experience and knowledge such as Condoleezza Rice, Francis Fukuyama, and many others.

Because it operates at such a high level for a unique clientele, getting into Seminar XXI isn't as simple as applying for a typical academic program. Participants have to be nominated and sponsored by their individual organizations, whether military branch, government agency, or nongovernmental organization, and it's a competitive process for a limited number of spots. Once admitted, participants are introduced to the program's three-pronged structure, combining "paradigms" (the varying worldviews of governments, peoples, and cultures); social science theories that can help explain and predict events and developments; and empirical knowledge based on historical facts, research, and practical experience. The idea is to engage a broad range of creative approaches to encourage fellows to think outside the usual boxes into which their past training and professional experience have too often limited them.

The latest program, which began in November 2017, includes sessions on cybersecurity and biosecurity; Iran, Turkey, and Israel; democracy and authoritarianism in the Arab world; and US national security policy. At the end of the nine months, Seminar XXI fellows receive a certificate and the satisfaction of knowing that they've become part of an elite group of graduates—a cohort of more than 2,100 military and civilian fellows who, over more than three decades of the program, have gone on to hold positions such as Deputy Secretary of Defense, Supreme Allied Commander in Europe, Vice Chairman of the Joint Chiefs of Staff, and directors of both the CIA and the National Security Agency. –Mark Wolverton

Framing Uncertainty

A landmark platform models the range of ways a changing climate may affect humanity, and vice versa



Reilly and Prinn

The barrage of hurricanes that in 2017 pummeled the Caribbean islands, United States, and even Ireland—fueled in part by unusually balmy Atlantic Ocean temperatures—provided a glimpse of consequences that may accompany a warming planet. If left unchecked, climate change will act as a "threat-multiplier," increasing the probability and intensity of such extreme weather events, according to Kerry Emanuel '76, PhD '78, MIT's Cecil and Ida Green Professor of Atmospheric Science. The situation is exacerbated, Emanuel noted in a *Washington Post* editorial last fall, by policies that have enabled the number of people living in vulnerable coastal zones to triple, worldwide, since 1970.

How can we get a handle on both the natural and manmade facets of potential climate-related disasters? Fortunately, researchers at MIT's Joint Program on the Science and Policy of Global Change (of which Emanuel is a faculty affiliate) have, for nearly a quarter of a century, been developing a comprehensive tool for dissecting the full range of impacts of climate on people and people on climate. The Integrated Global System Model (IGSM) is a flexible, computerized platform that brings together detailed models of Earth's climate system (including atmospheric, oceanic, and terrestrial processes) and the human-driven economic system, illustrating the complex interactions between them. This framework is a lynchpin of the Joint Program, the mission of which is "to provide a sound foundation of scientific knowledge to aid decision makers in confronting future food, energy, water, climate, air pollution, and other interwoven challenges."

"Projecting climate change into the future requires an understanding of both the natural environment and of how human development occurs," explains Ronald Prinn ScD '71, TEPCO Professor of Atmospheric Science who co-directs the Joint Program with John Reilly, a senior lecturer at the MIT Sloan School of Management. "As industries grow bigger, and new industries emerge, how much air and water pollution and greenhouse gases will be produced, and how can we mitigate their environmental impacts?"

The IGSM is one of the earliest and most sophisticated attempts to model the subtle interplay between the human and natural worlds.

The IGSM is one of the earliest and most sophisticated attempts to model the subtle interplay between the human and natural worlds. About 50 environmental scientists, economists, and engineers from MIT, including students and postdocs, participate in the program. These researchers, whose findings are well represented in the peer-reviewed scientific literature, continue to launch inquiries that focus on new technologies or highlight specific issues such as climatic impacts on water and agriculture.

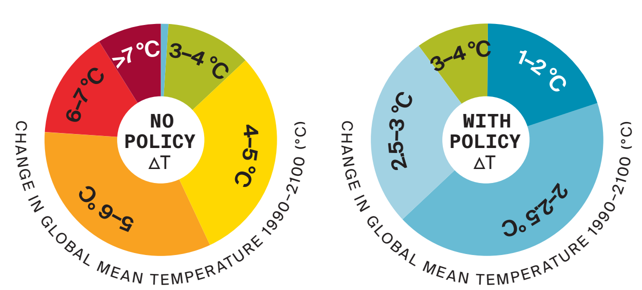
"A key goal of this undertaking," says Reilly, "has been to make our analyses relevant to public and private decision making, rather than leaving the IGSM as a purely scientific tool." A big challenge comes from combining two highly uncertain disciplines—environmental and economic sciences—and figuring out how to craft wise decisions. The IGSM, accordingly, does not attempt to provide exact predictions but instead offers a range of forecasts, which vary depending on the policies in place and the associated levels of human activity.

The Joint Program's 2016 Outlook report, for example, showed that even if all nations met their pledges to the 2015 Paris climate accord, the Earth's average temperature rise by 2100 would still exceed the established goal of 2 degrees Celsius or less. The authors then presented a set of emissions scenarios that could satisfy the 2 degrees C target, though complicated tradeoffs would arise. Increased energy production from the wind and sun means more land devoted to turbines and solar panels. An enhanced reliance on biomass energy could similarly take up land and water that might otherwise have been reserved for growing crops. Obtaining cooling water for power plants also gets harder as river temperatures rise.

"It's becoming ever more apparent that things we used to study separately are all interconnected," says Prinn. "Meanwhile, environmental changes are occurring far faster than expected, which is another way of saying the need for the IGSM is now greater than ever." –Steve Nadis

Nadis is a 1997–98 MIT Knight Science Journalism Fellow.

THE GREENHOUSE GAMBLE



The MIT Joint Program developed these roulette-style wheels to convey uncertainty in climate change prediction. Each shows the estimated probability of potential change in global average surface temperature by 2100, given scenarios with and without policies that mitigate emissions.

LEARN MORE
globalchange.mit.edu/gamble

PHOTO: SARAH BASTILLE

Facts on the Ground

David Hsu helps cities figure out what's working in the battle against climate change

When David Hsu was a vice president of the NYC Economic Development Corporation under then-mayor Michael Bloomberg, he was struck by two aspects of city government. The city had enormous power to implement policies that directly affected millions of residents—something that was especially apparent to Hsu in his role coordinating the rebirth of Lower Manhattan after the September 11 attacks. This responsibility was counterbalanced, though, by a frustrating truth. "I always felt like we didn't have enough information," says Hsu, since 2015 an assistant professor in MIT's Department of Urban Studies and Planning. That's what inspired him to enter academia. "I hope to bring a lot of academic rigor to that conversation."

When Hsu finished his PhD, he reached out to his former colleagues in New York City to see how academic research could advance the city's environmental goals. New York City had recently implemented an energy benchmarking policy that collected and published information about the energy use in the city's 10,000 largest buildings. The policy's goal was to create greater transparency for prospective buyers and tenants, to factor such information into property values, and above all to inspire building owners—many of whom had not, themselves, had previous access to such comprehensive data—to make energy improvements.

At the time, this was an untested strategy. City officials had a trove of data that they didn't know how to use or interpret. They asked Hsu to help in the effort to analyze and present the information efficiently. His findings were remarkable: the energy benchmarking policy reduced energy use in studied buildings by between 12% and 14% in four years. Similar benchmarking policies have now been adopted in 27 cities and two states, and are being actively promoted by the Department of Energy, the Environmental Protection Agency (EPA), and many environmental advocacy groups. These policies are influenced not only by New York City's success, but also by Hsu's research on how to improve benchmarking data and EnergyStar ratings, and how to use data-driven statistical learning to make accurate comparisons between diverse buildings.

Based on his experience studying the role information plays in encouraging investment in green infrastructure, Hsu was awarded a grant from the EPA to study barriers to implementing the Green City, Clean Waters program in Philadelphia. The program aims to avoid an expensive new sewer system by using fees and subsidies to encourage private property owners to build green infrastructure, such as rain gardens, to manage stormwater on 10,000 acres, or about a third of the city. Upon discovering that the biggest barrier to participation was lack of information regarding the costs, benefits, and logistics of adopting such infrastructure, Hsu and his team developed a prototype for a web portal that will provide property owners with information about how to reduce their fees, as well as connect them with contractors and financing sources. While Hsu's involvement in the four-year project ended last October, the City of Philadelphia plans to expand the prototype into a full-fledged website within the next year.

Hsu's analysis of New York City's energy benchmarking policy helped spur the adoption of similar policies in 27 other cities.

PHOTO: KATHERINE SHOZAWA

With his research in New York City and Philadelphia winding down in 2017, Hsu is turning his focus toward electrical grids in both the developed and developing world, including studying experimental microgrids in India. He's also working with several colleagues at MIT to study how policies and technology have contributed to the falling cost of solar panels, and is discussing options for studying several cities' plans to reduce carbon emissions by 80% by 2050.

Helping cities understand what is and is not working is the cornerstone of Hsu's ongoing research. "Urban environmental policy has a high impact on a lot of people," Hsu says. "It's honestly where the battle to mitigate climate change is going to happen." —Emily Omier

Energizing Global Environmental Cooperation

How Valerie Karplus and her transpacific team helped to put climate-critical commitments on the table

They called it "fog." When Valerie Karplus SM '08, PhD '11 was living in Beijing in 2002, few seemed bothered by the haze that regularly settled over the city. Karplus—now the Class of 1943 Career Development Professor and an assistant professor of global economics and management at MIT Sloan School of Management—was in China writing a book about biotechnology in the agriculture industry when she became interested in the country's environmental challenges.

China's rapid economic growth during the 2000s was largely powered by coal, which was causing severe local air pollution and contributing to the global rise in climate-warming greenhouse gases. She began to wonder: "How could we innovate in a way that would address these two interlinked challenges at the same time?"

Karplus returned to the US in 2006 to enroll in MIT's Technology and Policy Program (TPP). She recalls, "In TPP, we realized that although technology would be vital to solving grand challenges, meaningful change would require engaging stakeholders and building consensus." Little did she know that her group's work would eventually play a role in breaking a climate-critical impasse between the US and China.

After earning her doctorate, Karplus became director of the MIT-Tsinghua China Energy and Climate Project, a partnership between MIT's Joint Program on the Science and Policy of Global Change (see page 15) and the Institute of Energy, Environment, and Economy at China's leading engineering school, Tsinghua University. Through several years of personnel exchange and side-by-side work sessions, Karplus's team developed a detailed model of the country's economy and energy system that projected the potential long-term impact of different policy initiatives. The team's results have shown the value of implementing national climate targets by pricing CO_2, a system the Chinese government began piloting in 2013.

At the time, the US and China were in a major stalemate over which nation would lower its emissions first. While the US claimed its own actions would be futile without addressing China's higher and growing emissions, China maintained that developed nations like the US should take the lead in cutting carbon. Key to arguments on both sides were projections that China's fossil energy usage would climb with no end in sight. In contrast, results from the MIT-Tsinghua model, shared with policy makers in both nations, suggested China's energy-related CO_2 emissions could peak by 2030 without undermining its economic development.

The US and China made a historic agreement in 2014 that both sides would limit climate-related emissions—setting the stage for the larger global agreement in Paris in 2015. "It completely changed the game," Karplus says, "and created tremendous momentum for other countries to put serious commitments on the table."

Karplus has continued to work with colleagues at Tsinghua University to study the Chinese energy sector, researching the impacts of tailpipe emissions standards and renewable energy targets along with the design challenges associated with the carbon trading system soon to be implemented in China nationwide.

Karplus has used her expertise on China's economy and energy system to help the country project the long-term impact of different policy initiatives.

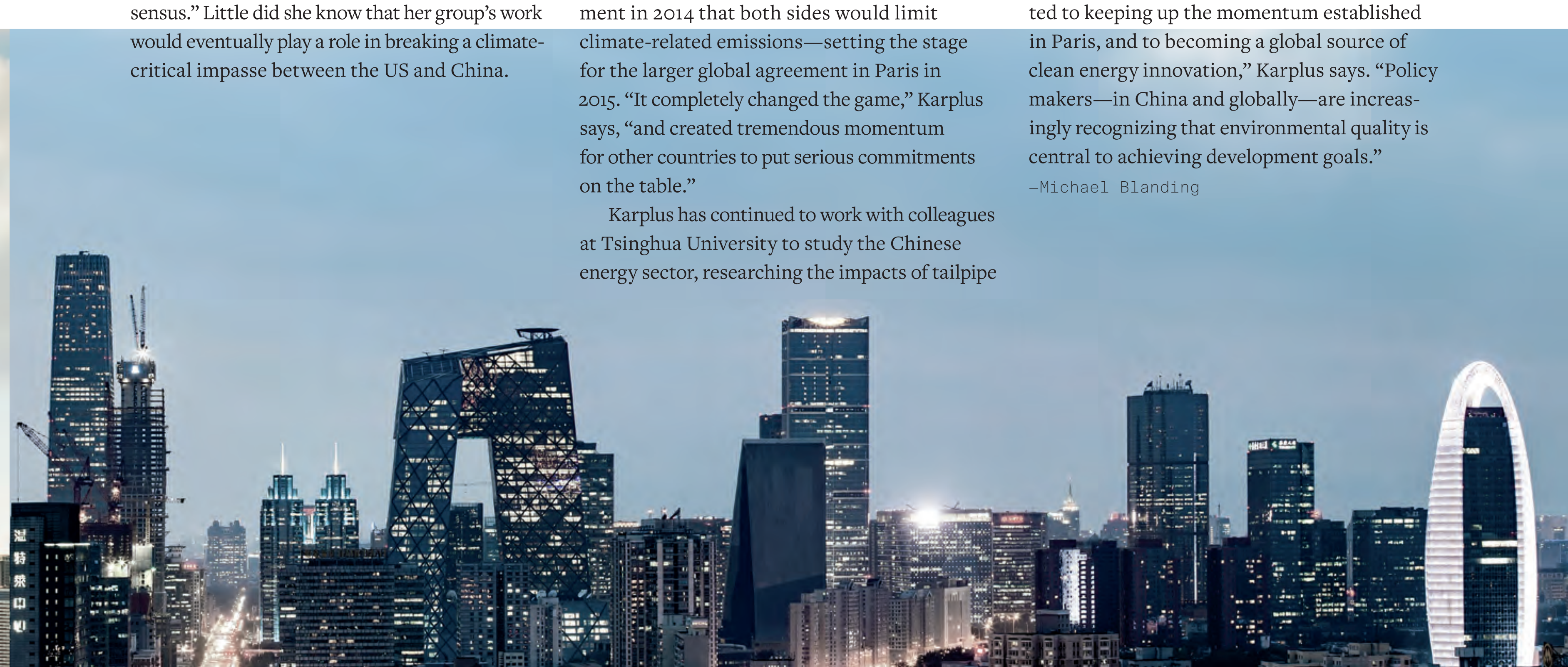
PHOTO: MIT SLOAN

"I see our role as being a provider of analysis as well as a catalyst for stronger cooperation between nations when it comes to the management of critical infrastructures like energy," she says.

Karplus and her transpacific colleagues have expanded focus beyond policy design to policy implementation. One sticking point for progress on China's environmental challenges has been that elements of its energy policy are fractured and piecemeal, with constantly changing requirements—one day mandating end-of-pipe scrubbers on coal plants, the next banning coal altogether in favor of natural gas. Karplus's team is now studying the system-wide enablers of effective policies, focusing on what drives compliance and innovation in firms and industries.

Even though the US has indicated it will pull out of the Paris Accord, "China is committed to keeping up the momentum established in Paris, and to becoming a global source of clean energy innovation," Karplus says. "Policy makers—in China and globally—are increasingly recognizing that environmental quality is central to achieving development goals."

—Michael Blanding



NYC: YUBO / GETTY IMAGES; BEIJING: DUKAI PHOTOGRAPHER / GETTY IMAGES

At the Intersection

Five grad students on finding their own routes into the policy sphere

MAYARA FELIX

PhD candidate, Economics

Research focus
Labor economics, development, and trade, including projects with the School Effectiveness and Inequality Initiative (SEII) studying the effects of disciplinary measures on learning, and with the Abdul Latif Jameel Poverty Action Lab (J-PAL) evaluating tax reform in Indonesia.

Policy perspective
"The research-to-policy connection takes three types of players: the academics, who are focused on the question itself, no matter what the answer is; the policy makers, who have a whole universe of considerations to take into account; and in the middle, crucial institutions like SEII and J-PAL that can talk both languages and facilitate dialogue through long-established relationships. It also takes tremendous patience, since it's the piled-up evidence, not one study alone, that will make a huge difference."

On bringing her dissertation home
"For my dissertation, I hope to shed light on how trade policy has affected the way firms compete for workers in Brazil, my home country. Competition is an abstract concept, but it's a real force that pushes an economy one way or another. Partnering with governments to access large administrative datasets on workers and firms is a key step in elucidating complex issues like this."

DANIEL GILFORD

PhD candidate, Earth, Atmospheric and Planetary Sciences

Research focus
Factors determining hurricanes' thermodynamic "speed limit"; effects on sea level of short-lived human-emitted greenhouse gases. Other activities: Weekly student lunches with the Joint Program on the Science and Policy of Global Change.

Policy perspective
"Understanding what intensifies hurricanes could improve prediction, helping officials make preparations and decisions related to evacuations, infrastructure, and disaster relief. Regarding sea-level rise, the policy implications are straightforward: to limit long-term sea-level rise, we must reduce climate pollutant emissions—as we did with CFCs in the Montreal Protocol, in which my advisor Susan Solomon [Lee and Geraldine Martin Professor of Environmental Studies] played an important scientific role. Of course, *how* to do this, including what the role of regulations is versus the market, is more nuanced."

On listening
"Policy is not just about talking to politicians. If you want something to change, you need to start with community outreach and engagement and most importantly, listening. People's values, goals, hopes, fears, dollars, security—these things don't directly affect my day-to-day science but play a major role in policy decisions. If I can't communicate the links between my work and those human aspects, then it's not going to be very effective."

(↗)
READ MORE
Which faculty members have helped to inspire these students' policy work?
spectrum.mit.edu/gradpolicy

SAMANTHA ZYONTZ SM '16

PhD candidate, Technological Innovation, Entrepreneurship, and Strategic Management

Research focus
How breakthrough technologies affect the interests and production of innovators. Other activities: Served as research assistant for US Cluster Mapping Project and the MIT Regional Entrepreneurship Acceleration Program (REAP).

Policy perspective
"From my intellectual property and law and economics roots, thinking through policy implications of my research will always be a natural inclination for me. Innovation does not occur in a vacuum. For example, I co-authored a paper about the types of scientists who experiment with the DNA-editing system CRISPR, and who is successful with it. We found that scientists who experiment are different on a number of important dimensions from those who can successfully turn that experimentation into a new project. This has implications for how policy makers or companies might want to target their adoption policies and programs."

On innovation clusters
"Kendall Square in Massachusetts is a phenomenal example of an area where a concentration of companies from the same industry (such as biotech) are bolstered by complementary industries and institutions. The question for the US Cluster Mapping Project became: Could we help key decision makers determine which clusters suit their geographic area? Not every location can be the next Silicon Valley, but some are primed to be the next footwear or automotive cluster. Our role as researchers is to make sure policy makers get all the correct information and be creative in developing tools and strategies that they can implement. Essentially, we show them how the rubber meets the road."

PHOTOGRAPHED IN KENDALL SQUARE BY M. SCOTT BRAUER

REED JORDAN

Master of City Planning candidate

Research focus
What cities can do to address racial inequality and exclusion through housing and economic development. Other activities: Evaluated a new performance management process for local housing authorities through the Massachusetts Department of Housing and Community Development.

Policy perspective
"The particular policy strategies for using housing to address neighborhood inequality are well-studied, and the need is obvious and enormous, but the collective public will is commensurately lacking. My research has turned toward how to expand and diversify the underlying political constituency necessary to make these policies a reality. I have hope that ever-rising income inequality can draw a white working-class constituency away from white nationalism and into coalitions with immigrants, poor blacks and Latinos, and millennials to be a basis for a renewed investment in affordable housing."

On generational impact
"When I was very young I learned from my family's history about divergent paths in wealth building. My white grandfather returned from WWII and was rewarded for his service with a generous slate of federal subsidies for his health care, education, and housing. This allowed his family to build considerable wealth even while he was the sole breadwinner as a high-school arts teacher. My black grandfather of a similar age, a highly educated Methodist minister, would have never been able to access these benefits because of the discriminatory design during this period of the Federal Housing Administration and Veterans Administration mortgage and student loan programs."

ABIGAIL REGITSKY

PhD candidate, Materials Science and Engineering

Research focus
Creating materials such as industry-customized calcium carbonate in a sustainable way. Other activities: Graduate Student Council (GSC), MIT Waste Alliance, MIT Science Policy Initiative (SPI).

Policy perspective
"An interest in sustainability shaped my choice to do research in the Laboratory for Bioinspired Interfaces, and I became interested in policy as another way to drive sustainability-related changes. Through SPI, I've learned how governmental science funding works and how to advocate for maintaining it. We visit DC to tell personal stories about our research and put faces to the funding. A large part of what we do on the GSC External Affairs Board is also to advocate on behalf of the MIT graduate student body at various levels of government on issues ranging from immigration to sexual violence on higher education campuses to road safety. Last summer, for example, I was able to go to a hearing at the Massachusetts State House to give testimony in support of a bill for enacting a carbon fee."

On career paths
"Maybe because I've been exposed through my extracurricular involvement to these policy issues, I've transitioned from wanting to be the researcher in the lab to wanting broader involvement in the policy side of things. My current plan after I get my PhD is to apply to science policy fellowships, many of which are available through the American Association for the Advancement of Science, and to work for a year as a staffer on the Hill."

(↗)
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Legal/ Code

MIT engineering students team up with Georgetown lawyers-in-training on internet privacy legislation

Every spring, engineering students from MIT and law students from Georgetown University overcome the distance between their institutions and disciplines in a semester-long flurry of virtual classroom meetings and late-night Google hangout sessions, culminating in presentations to policy experts in DC. "It's like a fusion of MIT technical talent and legal knowledge from Georgetown," explains Andrew Bartow, a senior in computer science who took the class his sophomore year. "Together we try to write a law that improves the state of internet privacy in the United States."

Now in its fourth year, 6.S978, Privacy Legislation: Law and Technology was born in part out of co-instructor Daniel Weitzner's experience in the White House as Deputy Chief Technology Officer for Internet Policy. "We were in need of more technically grounded, objective research to help us assess policy options. And it was frankly hard to figure out who to hire to work on these issues," recalls Weitzner, a principal research scientist at the MIT Computer Science and Artificial Intelligence Lab (CSAIL) who founded the MIT Internet Policy Research Initiative (see sidebar). Returning from Washington to MIT, Weitzner decided to create a course that could help engineers and lawyers bridge that gap. At the start of the course—which Weitzner teaches with Class of 1922 Professor of Computer Science and Engineering Hal Abelson PhD '73—15 Georgetown law students come to MIT for a day and join 15 MIT engineering students for what Weitzner calls a "boot camp" on privacy law and technology. From there, weekly meetings are held in a virtual space that merges physical classrooms at MIT and Georgetown.

Students also form small groups, each composed of two law and two engineering students, that spend the semester drafting legislation related to a particular technology, ranging from smart thermostats to self-driving cars. For the last class, MIT students fly to DC, and each group presents its proposal to a panel that has included senators, federal trade commissioners, policy leaders in industry, and policy advocate groups.

"They really do outstanding work, and I would say the ideas that they develop and the kind of seriousness with which they present them are really every bit as good as a lot of the ideas for which I was on the receiving end when I was sitting in the White House," Weitzner says, adding that some proposals have generated interest among state policy makers and legislators, and others have been published in technology law reviews at Yale and Harvard.

MIT students fly to DC and present proposals to a panel that has included senators, federal trade commissioners, policy leaders in industry, and policy advocate groups.

Bartow's project focused on law enforcement access to data gathered by in-home smart devices like an Amazon Echo or a Google Nest thermostat: he recalls his group carefully cross-referencing the Electronic Communications Privacy Act with the Google Nest policy on one screen and the Amazon Echo policy on another.

"What we discovered is that if you had a lot of these devices in your home, law enforcement could really get a pretty intimate picture of what's going on in your home without ever having to go to a court and get a warrant," Bartow explains. "There's a gap in the law that you could drive a truck through."

Closing that gap proved tricky—Bartow describes going back and forth with the law students in his group to address concerns for individual privacy without impeding the progress of technology or interfering with the needs of law enforcement. However, Bartow says practicing that interdisciplinary communication was one of the most valuable parts of the course. "A lot of problems, whether it be internet privacy or global warming, take a combination of technical problem solving and smart policy making to get the job done," he observes.

Last April, students from MIT, including Mary DuBard and Sunoo Park (opposite), pitched their bills to judges including Jay Edelson of Edelson PC and Uber's Betsy Masiello (above).

PHOTOS: BILL PETROS PHOTOGRAPHY

Sunoo Park SM '15, a PhD candidate in computer science, became interested in privacy law while conducting her doctoral research on cryptography. Last spring, her 6.S978 group drafted a bill that would more clearly define when and how law enforcement can access location data (e.g., GPS) from people's personal devices. "The existing laws were not designed with the technological landscape of today in mind, in most cases, and the technology has changed the way that people interact with their devices on an everyday basis," she notes.

Park says the course provided her with a deeper understanding of the components of effective legislation: "It was interesting to think about what is important to be written down or might be reasonably left open to interpretation." She also appreciated how the class revealed some of the unresolved questions engendered by the pace of innovation in her field. "One of the challenges is that tech is changing so fast," she says, "and typically laws don't change so fast."

Weitzner is pleased when his students come away from 6.S978 energized by such challenges. "A core mission of MIT's new Internet Policy Research Initiative is to help students discover how they can contribute to solving internet policy challenges," he says. "To a lot of people, the law is sort of a black art, and to a lot of other people, computer science is a black art. I think the engineering and law students see they can cut through whatever mystery there is—but that they need each other to do it."

—Catherine Caruso SM '16

Policy Research Targets Cybercrime

As online shopping and personalized digital experiences become commonplace, so, unfortunately, do data breaches and the exploiting of stolen information. According to a recent Pew study, a majority of Americans say they have been personally affected by data theft.

The impact of cybercrime extends beyond the personal: it's a growing issue for governments and companies tasked with ensuring critical infrastructures are secure. How can energy grids be protected from attacks such as the 2015 cyberassault that left nearly a quarter-million Ukrainians in the dark? What happens when a company's data are held for ransom? The answers will require more than technical savvy. Coordination between public and private sectors is necessary to develop effective digital and cybersecurity policies.

With these challenges in mind, MIT's Internet Policy Research Initiative (IPRI) awarded $1.5 million in grants last spring to five research projects at the intersection of internet policy and cybersecurity. According to IPRI founder Daniel Weitzner (see page 20), "Each project is aimed to support innovative research in [the recipients'] respective fields and result in new insights that can guide policy makers in making wise choices on pressing internet policy challenges." As these examples show, technology and policy are intertwined in both the problems and the solutions.

Cybersecurity Impacts on International Trade

PRINCIPAL INVESTIGATORS: Simon Johnson PhD '89, the Ronald A. Kurtz Professor of Entrepreneurship and Professor of Global Economics and Management; and Stuart Madnick '66, SM '69, PhD '72, the John Norris Maguire Professor of Information Technologies and Professor of Engineering Systems

Internet-enabled products—TVs, smartphones, medical devices, even toys—present unique challenges for global security and international trade policies. Johnson and Madnick—the latter directs the Cybersecurity at MIT Sloan initiative (formerly (IC)^3)—are examining how governments should deal with the import of items that could be used for malicious purposes, such as spying on citizens. Among their research goals: developing methods to weigh the risks of such imports, exploring the long-term impacts on trade, and developing a framework to guide policy makers as they construct agreements with foreign governments.

Using AI Planning Techniques to Analyze Urban Critical Infrastructure Vulnerabilities

PRINCIPAL INVESTIGATOR: Howard Shrobe SM '75, PhD '78, Principal Research Scientist, CSAIL

From water supplies to transportation networks, urban infrastructure is increasingly reliant on computerized industrial control systems. How can these essential systems be safeguarded against malicious attacks? Shrobe, who directs MIT's CyberSecurity@CSAIL initiative, is developing a method to automatically detect system vulnerabilities and to generate potential countermeasures that could be integrated with local policy to protect smart cities. A big-picture view will enable informed, long-term policy making, in contrast to what Shrobe calls a piecemeal "patch and pray" approach. —Stephanie Eich

Defining the Dilemmas of Artificial Intelligence

Media Lab researchers are part of a growing movement at MIT to explore the regulatory frontiers of AI—in society and in our hearts and minds

Kate Darling places a dinosaur robot the size of a housecat on the table, and flips the power switch on its belly. The dinosaur, which Darling calls Mr. Spaghetti, purrs to life. He lifts his little green head and closes his blue eyes affectionately as she rubs his neck. "He has touch sensors in his head and on his back," she explains. "They develop their own personalities depending on how you treat them."

Mr. Spaghetti is a Pleo, a "next-generation robotic companion pet" manufactured by a company based in Hong Kong. Darling, an expert in social robotics, has four Pleos scattered around her apartment, including a feisty one named Yochai and a shy one named Peter.

She holds up Mr. Spaghetti by his tail. A few seconds later, the onboard tilt sensor sends the little dinosaur into distress mode. Mr. Spaghetti starts to bleat and contort. "He's not happy," says Darling. More than that, in this moment Darling isn't happy either. It's what struck her when she first got Yochai a decade ago. "I found myself getting distressed when it mimicked distress. I wanted to know why I was responding like this even though I knew it was all fake." That is, why was she having these feelings for Yochai but not for a smoke alarm crying out for its batteries to be replaced? And what were the moral implications of developing an emotional tether to a dynamic, social robot?

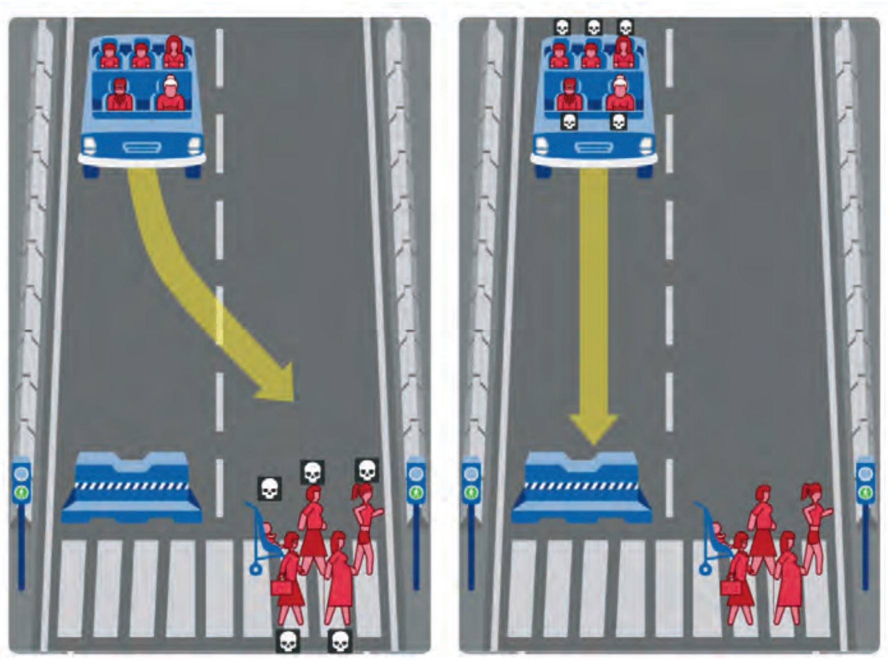
New Norms

When Darling arrived at the MIT Media Lab as a research specialist, she befriended a handful of roboticists. She told them about the questions that her pet dinosaurs had conjured for her. Darling and the roboticists soon realized they each had something to offer the other. For instance, the engineers were designing a robot to interact with kids in the hospital. Immediately, Darling—who holds both a doctorate and a law degree—started racing through the ethical implications of such a robot: what kinds of information would it be collecting and would that be in violation of hospital privacy policies? The roboticists admitted these questions had never crossed their minds. "I used to think that the technologists' job was to build the stuff," Darling says, "and it was my job as a social scientist to come in later and figure out how to regulate it." But she learned that design decisions made early on, which can be hard to adjust subsequently, can and should be informed by ethical and regulatory considerations.

As integrating robots into our daily lives becomes imminent, Darling has a new pair of questions: what kind of society do we hope to create through the use of robotic technologies, and what policies will guide us in that direction? The complexity of the scenarios that need addressing ratchets up fast.

Let's return to Mr. Spaghetti. In response to his distress, Darling felt distress. But there are other behavioral responses. After holding the dinosaur up by his tail repeatedly, you might get desensitized to his cries imploring a return to the horizontal. You might even inflict vertical panic on him intentionally. Darling thinks about what that means for someone's subsequent interactions with *real* beings. In her words, "harm arises when you start treating the real dog the way you treat the robot dog."

When the robots are humanoid, and their potential uses are so open-ended, the notion of an emotional tether becomes even more fraught. In a world populated by ever-more-lifelike toys and tools, what are the norms for how we engage with them? How should policy prescribe those norms? For instance, just like with that hospital robot, what types of data are AI-powered household assistants such as Alexa gathering about us, and how should that harvest of information be regulated? Might robots that are engineered to be especially likable manipulate us into sharing more details about our lives?



The Scalable Cooperation Group's "Moral Machine" has asked millions of people around the world to weigh in on a variety of life-or-death scenarios autonomous vehicles may face.

SCREENSHOT: COURTESY OF SCALABLE COOPERATION GROUP

PHOTO: JUSTIN SAGLIO / EMTECH MIT

PHOTO: FLAVIA SCHAUB

What are the moral implications of developing an emotional tether to a dynamic, social robot?

In addition to producing well-reasoned articles on such topics, Darling attends conferences that bring together technologists and lawmakers under the same roof. During the Obama Administration, she met with the Office of Science and Technology Policy to help advise them on two reports, one on artificial intelligence more broadly and one on the intersection of AI and jobs. "I try to not just stay within academia," Darling describes, "but actually talk to people who are making policy in the hopes that something can be done."

Such dialogue may soon have new fodder thanks to a new multidisciplinary endeavor—recently announced by the MIT Media Lab and the Berkman Klein Center for Internet and Society at Harvard University—to investigate the ethics and governance of artificial intelligence. The effort intensifies MIT's commitment not just to develop new technologies but to understand and guide how such advances may transform society. Darling is one of numerous researchers at MIT—within the Media Lab, as well as in departments ranging from physics to political science to computer science to information technology—who are laying the groundwork now for the social and legislative ramifications of AI's future.

The Swerve

On the fourth floor of the Media Lab building, a framed illustration stands on an easel. It depicts blocky, pixelated objects, like those in an old video game. A blue car is whipping along a city road. Half of the intersection ahead is blocked by a concrete barricade. A father and his daughter are walking their dog across the open part of the road. There's not enough time for the car to brake safely. Swerve to avoid the pedestrians, and the two passengers in the car—a mother and her son—won't survive the collision with the barricade. Stay on course, and the father and daughter will suffer a fatal hit.

(↗)
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See page 35 for news about the MIT Intelligence Quest, a major new initiative at the intersection of human and artificial intelligence.

It sounds like a variation on the classic "trolley problem"—a term coined by MIT philosopher Judith Jarvis Thomson in 1976. The twist is that the blue car is a self-driving vehicle. In this hypothetical scenario, the car decides whether to kill its occupants or strike the pedestrians ahead. What kind of moral and legal constraints should inform the car's decision? And how should policy makers enforce those constraints? "The ethical question at the heart of AI is about a new type of object," says Iyad Rahwan, AT&T Career Development Professor of Media Arts and Sciences, leader of the Media Lab's Scalable Cooperation group, and affiliate faculty at MIT's Institute for Data, Systems, and Society. "This new object is no longer a passive thing controlled by human beings. It has agency, the ability to make autonomous choices, and it can adapt based on its own experiences independent of its design." Rahwan commissioned the illustration of the blue car to highlight one possible moral dilemma that an autonomous vehicle might face. There are countless others.

To get at whether there are any guiding ethical principles when it comes to the kinds of ambiguous scenarios a car might face, Rahwan and others in his lab created an online poll of sorts called the Moral Machine, in which participants are presented with morally charged setups similar to the one in the illustration. The Moral Machine went viral. Almost three million people from all over the world have clicked through the scenarios. Rahwan's team translated the experience into nine languages including Arabic, Chinese, and Russian. They're still working up the results but a couple of things are clear. "Almost every person has something to say about this," observes postdoctoral fellow Edmond Awad SM '17, one of roughly 20 researchers and students in Rahwan's group. "And we found broad cultural differences between eastern countries and western countries."

One paradox that's emerged from this study and others is even though consumers agree that self-driving cars should make decisions that minimize fatalities, these same people are less likely to buy a car programmed to sacrifice its occupants according to that rule. Sydney Levine, another postdoc in Rahwan's group, refers to this as the "tragedy of the algorithmic commons." There's urgency to resolving the paradox, though. "Getting self-driving cars on the road quickly is going to save lots of lives," she says, "reducing the number of traffic accidents by 90%."

What's clear is that the ethics of our machines will reflect the ethics of ourselves, "which forces us to articulate our own ethics more explicitly," says Rahwan. "So in a way, the development of AI can make us better humans" because it's pushing us to question who we are and define what we want our world to be. When it comes to making policy to guide AI, Rahwan says the difficulty is developing regulations that allow people to feel at ease with and trust something like a driverless car without stifling innovation. In that spirit, his group is also working on algorithms that improve human-computer cooperation and even exploring the use of emojis in training machines to better understand human emotion.

On a personal level, there's an even deeper urgency motivating Rahwan's research. He was born in Aleppo, Syria, where he recently witnessed the rapid and wholesale collapse of Syrian society and institutions. "I want to help come up with a new way of running the world that's more robust," he says. He acknowledges, from personal, painful experience, that humans are fallible. So he's hoping to make machines that learn from our failings to help strengthen our communities and social fabrics. In other words, Rahwan believes that artificial intelligence has the power to make us more human, not less. —Ari Daniel PhD '08

Hands on the Wheel

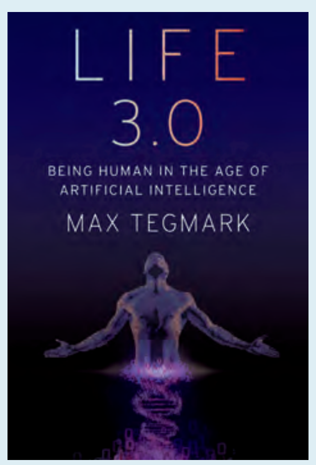
Excerpts from new faculty books pose questions we must answer as AI begins to reshape society

Life 3.0: Being Human in the Age of Artificial Intelligence **(Knopf, 2017)**

By Max Tegmark, professor of physics, founder of the Future of Life Institute

In order to reap [the] benefits of AI without creating new problems, we need to answer many important questions. For example:

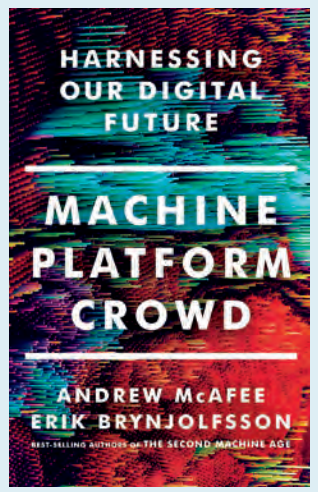
1. How can we make future AI systems more robust than today's, so that they do what we want without crashing, malfunctioning or getting hacked?
2. How can we update our legal systems to be more fair and efficient and to keep pace with the rapidly changing digital landscape?
3. How can we make weapons smarter and less prone to killing innocent civilians without triggering an out-of-control arms race in lethal autonomous weapons?
4. How can we grow our prosperity through automation without leaving people lacking income or purpose?



These four near-term questions are aimed mainly at computer scientists, legal scholars, military strategists and economists, respectively. However, to help get the answers we need by the time we need them, everybody needs to join this conversation, because as we'll see, the challenges transcend all traditional boundaries—both between specialties and between nations.

From chapter 3, "The Near Future: Breakthroughs, Bugs, Laws, Weapons and Jobs"

Machine, Platform, Crowd: Harnessing Our Digital Future **(Norton, 2017)**



By Erik Brynjolfsson PhD '91, director of the MIT Initiative on the Digital Economy (IDE) and Schussel Family Professor of Management Science; and Andrew McAfee '88, '89, SM '90, co-director, IDE

Although we field many requests for advice on how a company can thrive in the digital era, some of the most common questions we get take a broader view: What does the machine-platform-crowd transformation mean for society? Will machines leave people unemployed? Will powerful platforms control all our economic decisions? Will individuals have less freedom to decide how and when they work, where they live, and who their friends are?

These are profoundly important issues. But too often, they are variants of a single question: What will technology do to us?

And that's not the right question. Technology is a tool. That is true whether it's a hammer or a deep neural network. Tools don't decide what happens to people. We decide. The lesson we've learned from studying thousands of companies over our careers is that while technology creates options, success depends on how people take advantage of these options. The success of a venture almost never turns on how much technology it can access, but on how its people use that technology, and on what values they imbue in the organization.

We have more powerful technology at our disposal than ever before, both as individuals and as a society. This means we have more power to change the world than ever before. [...] So we should ask not "What will technology do to us?" but rather "What do we want to do with technology?"

From the conclusion, "Economies and Societies Beyond Computation"

Tool Box

Three MIT-made online resources helping officials and the public get a handle on policy

Haitian Creole ("Kreyòl") resource library for STEM education

Origins

MIT linguistics professor and native Kreyòl speaker Michel DeGraff directs the **MIT-Haiti Initiative**, launched in 2010 in collaboration with Vijay Kumar (now associate dean of open learning), other MIT faculty and staff, and leaders in Haitian education. The main objective is to enhance STEM education in Haiti with active-learning pedagogy and technology and through the use of Kreyòl as language of instruction. In 2013, MIT-Haiti established a major agreement with the Haitian government.

The need

In 2015, Haiti's government, through an agreement between the Ministry of Education and the Haitian Creole Academy (of which DeGraff is a founding member), announced that it would promote Kreyòl as language of instruction at all levels of the school system. This represents a major break with a tradition whereby French has long been the exclusive language of formal education—a tradition that has impeded the learning of generations of Haitian students, the vast majority of whom are fluent in Kreyòl only. However, the availability and quality of educational resources for STEM in Kreyòl has not yet caught up to the new policy and will be critical to its implementation.

How it works

The initiative's website showcases a growing body of educational materials—particularly in STEM fields—in Kreyòl, ranging from digital learning tools to lesson plans to evaluation instruments. DeGraff and colleagues in the US and Haiti have also developed a glossary of new STEM-oriented coinages in Kreyòl to help extend the scope of the language in technical fields, and recently teamed up with Google to add these terms to the Kreyòl module of Google Translate.

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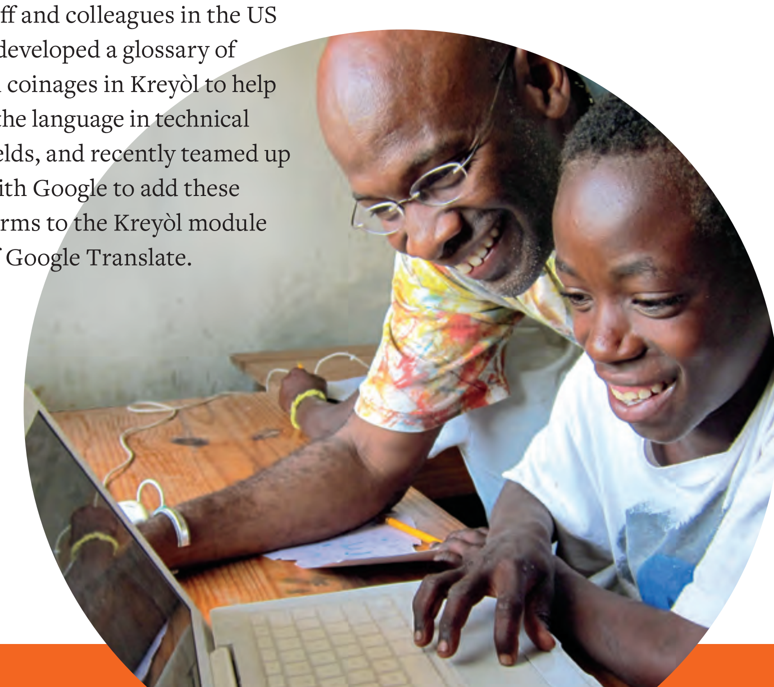
haiti.mit.edu/resources



DeGraff works with a Haitian student.

PHOTO: COURTESY OF MIT-HAITI INITIATIVE

Banking Reform Clearinghouse (BRiC)

Origins

BRiC was launched in summer 2017 by MIT Sloan School of Management's **Golub Center for Finance and Policy (GCFP)**, developed by research associate Kyle Shohfi SM '16 and research assistant intern Chris Lange MBA '18 under the leadership of the center's director, Sloan Distinguished Professor of Finance Deborah Lucas, and executive director Doug Criscitello.

The need

Financial regulatory reform is a hot topic with the recent passage of the Financial CHOICE Act of 2017 in the US House of Representatives and the current Administration's interest in amending the Dodd-Frank Wall Street Reform and Consumer Protection Act (2010). GCFP created BRiC as a nonpartisan educational tool for researchers, practitioners, and the general public.

How it works

BRiC organizes information related to the current debate on banking regulations, representing viewpoints from across the regulatory reform spectrum. Users can launch an interactive search by issue area (e.g., the Volcker Rule, the Consumer Financial Protection Bureau) or source. Each document is linked to its original site. Currently, BRiC's five main sources are the provisions of the Financial CHOICE Act; key recommendations from the US Department of the Treasury's June 2017 report; statements, speeches, and research reports from the Federal Reserve; articles, research papers, blogs, videos, and policy letters from think tanks and other academic institutions; and proposals pending in Congress that address key aspects of regulatory reform.

(↗) LEARN MORE
gcfp.mit.edu/bric

CITE Evaluation Report Library

Origins

The **Comprehensive Initiative on Technology Evaluation (CITE)** was founded in 2012 by Bishwapriya Sanyal, Ford International Professor of Urban Development and Planning. Supported through 2017 by grants from the US Agency for International Development (USAID), the cross-departmental initiative is now exploring structures for self-sustaining operation.

Above: In India, CITE's Susan Murcott demonstrates water sampling procedures to team member Shrikant Brahmbhatt.

PHOTO: JASON KNUTSON

The need

One of CITE's main goals is to provide data and analysis that will guide limited funding in the global development space toward the methods and products that work best. Its library of reports support data-driven decision making by development workers, donors, manufacturers, suppliers, and consumers themselves. Areas of focus include health (malaria rapid diagnostic tests, wheelchairs) and water and food (post-harvest storage, food aid packaging, water test kits and filters).

How it works

Consumer Reports was an early partner and inspiration for product evaluation techniques. CITE has evolved its model to address three criteria for the developing nation context: suitability (does a product perform its intended purpose); scalability (can the supply chain effectively reach consumers); and sustainability (is a product used correctly, consistently, and continuously over time). Reports organize findings and recommendations by stakeholder. For example, CITE's newest report evaluating solar-powered water pumps on the market in India pointed consumers toward two lower-cost products that outperformed more expensive counterparts, while suggesting the use of government policies—subsidizing the cost of solar equipment, paying for excess electricity production—to enable farmers' adoption of the technology.

—Nicole Estvanik Taylor

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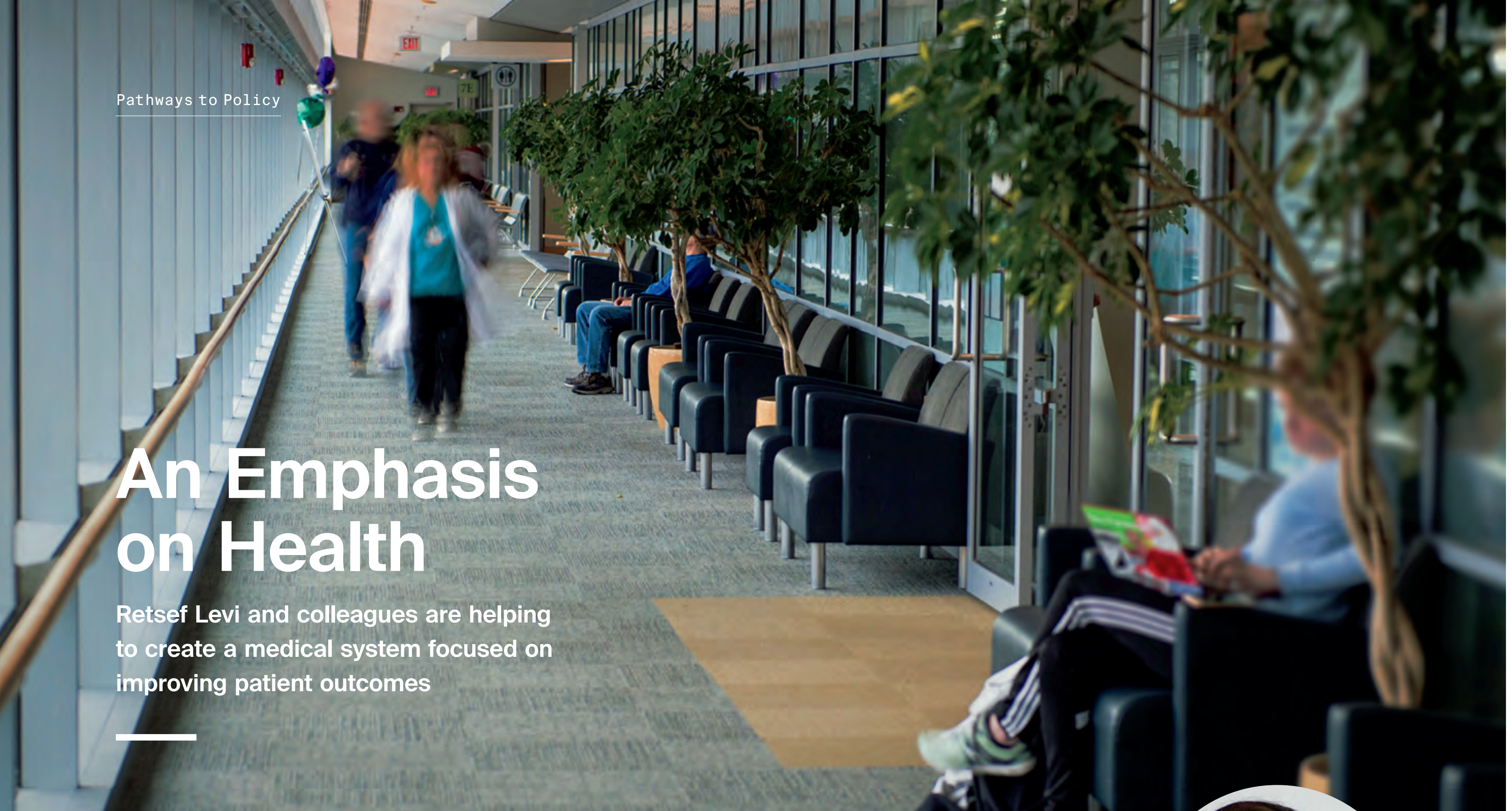
cite.mit.edu/reports



An Emphasis on Health

Retsef Levi and colleagues are helping to create a medical system focused on improving patient outcomes

Each year, the United States spends more than $9,000 per person on health care. Yet the world's most costly health care system is neither its most effective nor efficient. Citizens of other developed countries enjoy better health outcomes and longer lives at a fraction of the price. According to the Institute of Medicine and the American Medical Association, around 30% of US health care dollars are wasted through misuse of resources. Retsef Levi, professor of operations management at MIT Sloan School of Management, isn't sure he has all the answers to America's health conundrum. But he thinks that he and his many colleagues at MIT are asking the right questions.

"If you want to change a system, you first need to understand how that system came into being," says Levi, the J. Spencer Standish (1945) Professor of Operations Management at Sloan. "This country's health system started to develop inorganically in the early 20th century focusing on care for sick people in hospitals. These hospitals delivered their services in exchange for fees. As a result, we have a system that focuses on treating the sick, instead of one that helps people to stay well."

Born in Israel, Levi spent 11 years as an intelligence officer in the Israeli Defense Forces before earning degrees in mathematics and operations research. The latter discipline, he explains, is the science of leveraging data through models to inform decisions, particularly in a context of uncertainty. Levi and his colleagues use analytics and other quantitative methods to build data-driven models that help leaders and managers make decisions under the risks of an uncertain future.

Levi conducts research across a range of complex systems including supply chains, revenue management, and food safety. The uncertainties of health care, he says, are particularly complex—a unique web of technology, human behavior, politics, and culture. "Understanding the exact nature of the uncertainty is key," he explains. "For example, I can't predict exactly how many people will visit the emergency room at Mass General Hospital [MGH] on a specific hour and day in December. But I can build a model based on historical observations from the past three years on that day, and on similar days, and be able to get close to predicting."

For Levi, the increasing availability of data opens up exciting opportunities in health care. Until recently, it was very difficult to predict when hospital patients were going to be discharged. Now, with big data from the new electronic medical records system at MGH and advanced analytics techniques, Levi's MIT team and its MGH collaborators are able to predict daily discharges at an accuracy of over 90%. This enables providers to allocate resources more efficiently and substantially reduce patients' wait time. The collaborative team also works on developing timely outpatient interventions and predictive risk models to reduce unnecessary and costly hospital admissions.

Levi believes the most commonly prescribed remedy for the US health care system—focusing merely on creating incentives that encourage hospitals to limit treatment and thus save money—is destined to fail. "You cannot change performance just by changing your pay structure," he contends. "You need to design for performance, and then follow up with appropriate incentives."

A co-leader in MIT Sloan's Initiative for Health Systems Innovation, Levi is convinced that analytics coupled with human intelligence can help create a system designed to promote positive health outcomes and not just treat illness. "This requires a fundamental shift," says Levi. "Not just in the US, but across the globe. At the moment, we don't even have comprehensive metrics that can measure and help manage health outcomes."

"I believe we've been asking the wrong questions about our health care system to this point," says Levi. "Inefficient systems are not only costly, but are usually associated with bad outcomes. And our system is inefficient. Yet the only way to engage clinical teams to drive change is to focus on improving patient outcomes, which ultimately lead to lower cost and more efficient systems." –Ken Shulman

PHOTOS: SARAH BASTILLE (HOSPITAL); JUSTIN KNIGHT (LEVI)

Building the STEM-Capable Workforce of the Future

Why it's time for policies that expand the nation's vision for science and engineering education

The following is an excerpt of testimony delivered on March 21, 2017, by Maria T. Zuber before the Subcommittee on Research and Technology for the Committee on Science, Space, and Technology in the US House of Representatives. Zuber, who is MIT's vice president for research and the E.A. Griswold Professor of Geophysics, presented these remarks in her role as the chair of the National Science Board (NSB), which acts as the governing body of the National Science Foundation and as nonpartisan advisors to the President and Congress on matters related to science and education.

In July 1945, Vannevar Bush, the head of the Office of Scientific Research and Development during World War II and one of my predecessors at MIT, sent the White House a landmark report titled *Science: The Endless Frontier*. In that report, Bush outlined a vision for national investment in fundamental scientific research and the next generation of scientists. As Bush wrote in his letter of transmittal, "Science offers a largely unexplored hinterland for the pioneer who has the tools for his tasks. The rewards of such exploration both for the nation and the individual are great. Scientific progress is one essential key to our security as a Nation, to our better health, to more jobs, to a higher standard of living, and to our cultural progress." [...] The result of Bush's vision was the National Science Foundation (NSF). For nearly 70 years, NSF has catalyzed pioneering basic research in all fields of science and engineering. This research has opened new windows on our universe, made possible new industries, and given all Americans life-changing and life-saving technologies. [...]

Ensuring the long-term strength of the nation's scientific workforce has always been a core component of NSF's mission. Our workforce has been—and continues to be—the essence of American innovation, economic competitiveness, and national security. In 1950, Vannevar Bush wrote that "the responsibility for the creation of new scientific knowledge—and for most of its application—rests on that small body of men and women who understand the fundamental laws of nature and are skilled in the techniques of scientific research." At that time, and for the next several decades, this meant scientists and engineers engaged in research and development in government, academic, or industry laboratories.

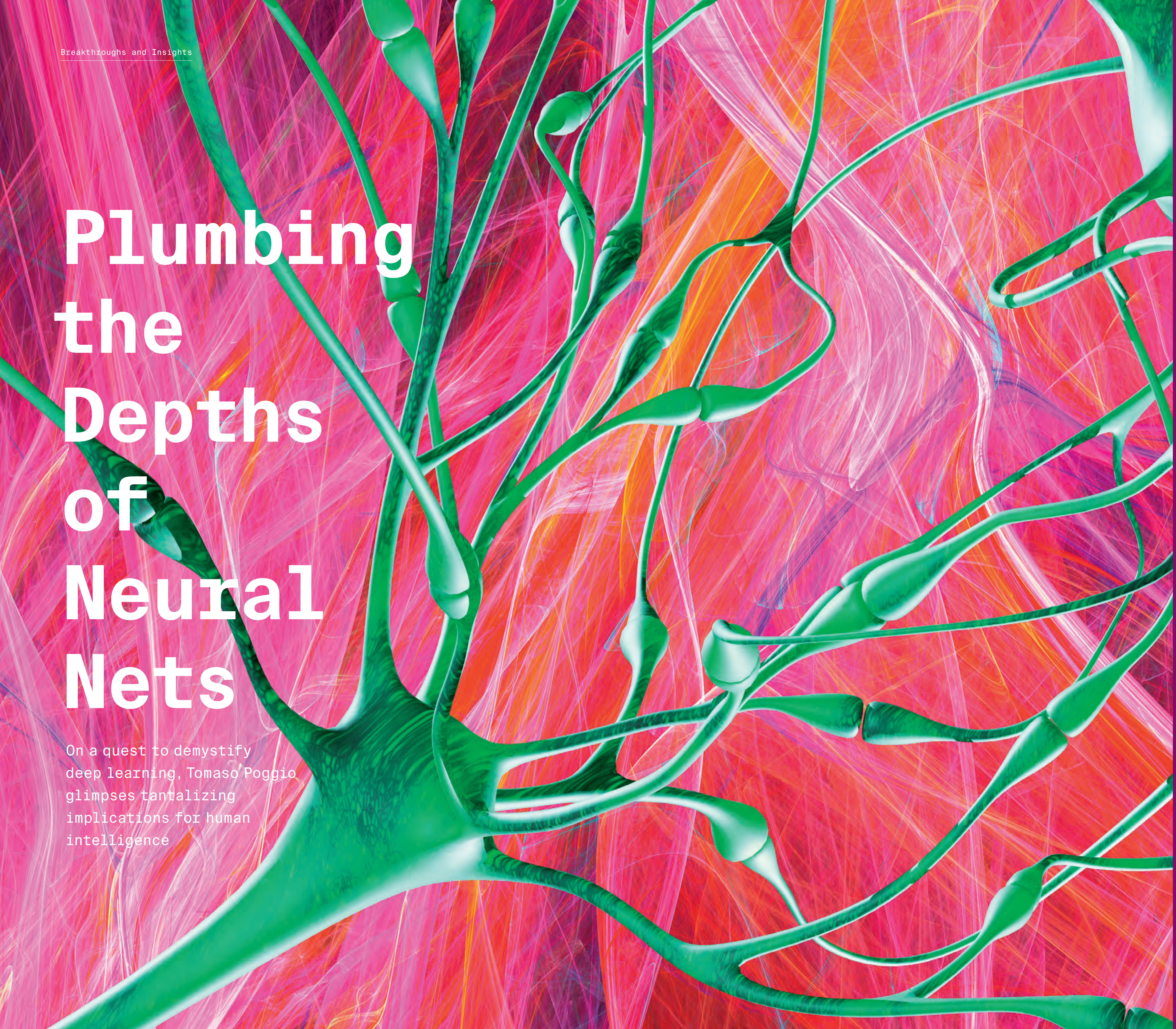
> Fostering a STEM-capable US workforce ensures that all Americans are prepared to meet evolving workplace demands.

How we think about this workforce has evolved—and expanded—since NSF's founding. While the education and training of scientists and engineers who perform fundamental research—our nation's "discoverers"—remains at the heart of NSF's mission, we now recognize that STEM capabilities are important to the entire US workforce. As we look towards the next 70 years, the NSB believes that for our nation to continue to thrive and lead in a globally competitive knowledge- and technology-intensive economy we must do more than create a "STEM workforce"; Congress, the Administration, business leaders, educators, and other decision makers must work together to create a STEM-capable US workforce.

Why is this so important to our nation's future? Scientific and technological advances have transformed the workplace, especially in traditionally middle-class, blue-collar jobs such as manufacturing. These and many other jobs now demand higher levels of STEM knowledge and skill. In 2013, about 13.3 million US workers were employed in a STEM job. Yet in a survey of individuals with at least a four-year degree, including many working in sales, marketing, and management, an estimated 17.7 million reported that their job required at least a bachelor's degree level of STEM expertise. And the number of non-STEM jobs requiring these skills is growing. Fostering a STEM-capable US workforce ensures that all Americans are prepared to meet evolving workplace demands. Likewise, it ensures that existing and new American businesses have the talent necessary to compete and win in a global economy.

Creating a STEM-capable US workforce requires a more expansive vision for STEM. This vision includes students and workers at all education levels, working on the farm, the factory floor, the laboratory, and everywhere in between using STEM capabilities to learn, adapt, install, debug, train, and maintain new processes or technologies. This vision includes women, traditionally underrepresented groups, and blue-collar workers who were hard hit by transformations in the domestic and global economy. This vision of a STEM-capable US workforce does not replace what Vannevar Bush originally envisioned. It builds on that foundation to more fully mobilize what he called the vigorous "pioneer spirit" within our nation and all of its people. –Maria T. Zuber

PHOTO: DOMINICK REUTER



Plumbing the Depths of Neural Nets

On a quest to demystify deep learning, Tomaso Poggio glimpses tantalizing implications for human intelligence

Talk to neuroscientist Tomaso Poggio for any length of time, and you're likely to learn more than one unexpected fact about brains, minds, or machines. Like, for example, the fact that the size of a fruit fly's brain—when the number of neurons are plotted logarithmically—lies almost exactly halfway between the human brain and no brain at all. "When I started my scientific career, I studied the brain of the fly," says Poggio. Nowadays, investigating that space between "brain" and "no brain" is what drives Poggio, the Eugene McDermott Professor of Brain and Cognitive Sciences, as he directs the Center for Brains, Minds, and Machines (CBMM), a multi-institutional collaboration headquartered at MIT's McGovern Institute for Brain Research.

IMAGE: LAGUNA DESIGN

CBMM's mission, in Poggio's words, is no less than "understanding the problem of intelligence—not only the engineering problem of building an intelligent machine, but the scientific problem of what intelligence is, how our brain works and how it creates the mind." To Poggio, whose multidisciplinary background also includes physics, mathematics, and computer science, the question of how intelligence mysteriously arises out of certain arrangements of matter and not others "is not only one of the great problems in science, like the origin of the universe—it's actually the greatest of all, because it means understanding the very tool we use to understand everything else: our mind."

One of Poggio's primary fascinations is the behavior of so-called "deep-learning" neural networks. These computer systems are very roughly modeled on the arrangement of neurons in certain regions of biological brains. A neural network is termed "deep" when it passes information among multiple layers of digital connections in between the input and the output. These hidden layers may number anywhere from the dozens to the thousands, and their unusual pattern-matching capabilities power many of today's "artificial intelligence" applications—from the speech recognition algorithms in smartphones to the software that helps guide self-driving cars.

"It's intriguing to me that these software models, which are based on such a coarse approximation of neurons and have very few biologically based constraints, not only perform well in a number of difficult pattern-recognition problems—they also seem to be predicting some of the properties of actual neurons in the visual cortex of monkeys," Poggio explains. The question is: why?

The truth is, nobody knows—even as the technology of deep learning accelerates at an ever-quickening pace. "The theoretical understanding of these systems is lagging behind the application," says Lorenzo Rosasco, a machine learning researcher who collaborates with Poggio at CBMM. To Poggio, this gap in fundamental theory is "pretty typical" for doing groundbreaking science. "People didn't really understand at first why a battery works or what electricity is—it was just experimentally found," he explains. "Then from studying it, there is a theory that develops, and this is what is important for further progress."

What Couloumb and Ohm did for electricity, Poggio wants to do for deep neural networks: to begin defining a theory. He, Rosasco, and a dozen other CBMM collaborators recently published a set of three papers that does just that. The field of machine learning already has several decades' worth of theoretical understanding applied to what Poggio calls "shallow" neural networks—generally, systems with only one layer in between the input and output. But deep-learning networks are much more powerful (as the latest tech-industry headlines readily confirm). "Basically there is no good theory for why deep networks work better than these one-layer networks," Poggio says. Each of his three papers addresses one piece of that theoretical puzzle—from the technical details all the way up to their (in Poggio's words) "philosophical" implications.

Breaking the Curse

The first paper in the trio has a disarmingly layman-friendly title: "Why and When Can Deep—but Not Shallow—Networks Avoid the Curse of Dimensionality: A Review." This "curse" may sound like something J.K. Rowling might dream up if she were writing a physics textbook. But it's actually a well-known mathematical thorn in the side of any researcher who's had to tangle with large, complex sets of data—precisely the kind of so-called big data that deep-learning networks are increasingly being used to make sense of in science and industry.

"Dimensionality" refers to the number of parameters that a data point contains. A point in physical space, for example, exists in three dimensions defined by length, height, and depth. Many phenomena of interest to science, however—for example, gene expression in an organism or ecological interactions in an environment—generate data with thousands (or more) parameters for every point. "These parameters are like knobs or dials" on a complicated machine, says Poggio. To model these "high-dimensional" systems mathematically, equations are needed that can specify every possible state of every available "knob." Mathematicians have proven that a one-layer neural network can—in theory—model any kind of system to any degree of accuracy, no matter how many of these dimensions (or "knobs") it contains. There's just one problem: "it will take an enormous amount of resources" in time and computing power, Poggio says.

The "curse of dimensionality" may sound like something J.K. Rowling might dream up if she were writing a physics textbook. But it's actually a well-known mathematical thorn in the side of any researcher who's had to tangle with large, complex sets of data.

Deep neural networks, however, seem to be able to escape this "curse of dimensionality" under certain conditions. Take image-classifying software, for example. A deep neural network trained to detect the image of a school bus in a 32-by-32 grid of pixels would be considered primitive by contemporary standards—after all, smartphone apps can routinely recognize faces in photos containing millions of pixels. And yet the number of parameters, or "knobs," in even that 32-by-32 pixel grid is astronomical: "a one followed by a thousand zeros," says Poggio. Why can deep-learning networks handle such seemingly intractable tasks with aplomb?

To Poggio and Rosasco (who co-authored the first paper with colleagues from the California Institute of Technology and Claremont Graduate University), the answer may reside in a special set of mathematical relationships called compositional functions.

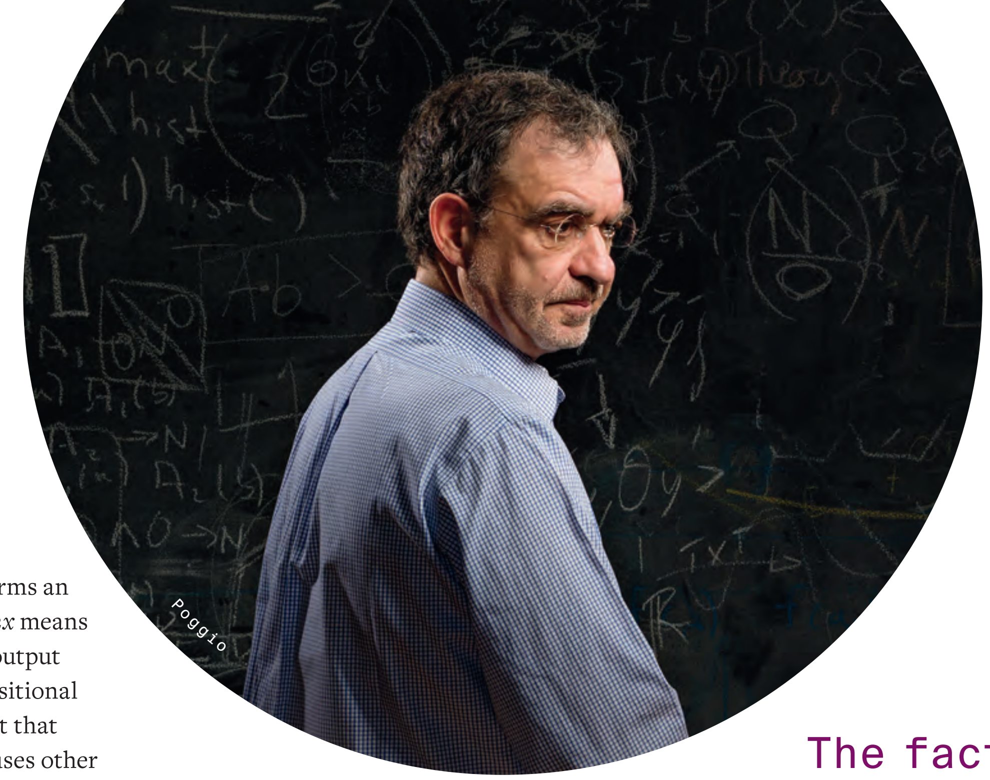

Poggio

PHOTO: JASON GROW

A function is any equation that transforms an input to an output: for example, $f(x) = 2x$ means "for any number given as an input, the output will be double that number." A compositional function behaves the same way, except that instead of using numbers as inputs, it uses other functions—creating a structure that resembles a tree, with functions composed from other functions, and so on.

The mathematics of this tree can become incredibly complicated. But, significantly, the hierarchical structure of compositional functions mirrors the architecture of deep neural networks—a dense web of layered connections. And it just so happens that computational tasks that involve classifying patterns composed of constituent parts—like recognizing the features of a school bus or a face in an array of pixels—are described by compositional functions, too. Something about this hand-in-glove "fit" among the structures of deep neural networks, compositional functions, and pattern-recognition tasks causes the curse of dimensionality to disappear.

Practical Magic

Not only does Poggio's theory provide a road-map for what kinds of problems deep-learning networks are ideally equipped to solve—it also sheds light on what kinds of tasks these networks probably *won't* handle especially well. In an age when "artificial intelligence" is often hyped as a technological panacea, Poggio's work demystifies neural networks. "There's often a suggestion that there is something 'magical' in the way deep-learning systems can learn," says Rosasco. "This paper is basically saying, 'Okay, there are also some other theoretical considerations that actually seem to be able to, at least qualitatively, make sense of this.'" In other words, if a complicated task or problem can be described using compositional functions, a deep neural network may be the best computational tool to approach it with. But if the problem's complexity *doesn't* match the language of compositional functions, neural networks won't "magically" handle it any better than other computer architectures will.

Poggio's other two theoretical papers also use clever mathematics to attempt to bring some other "magical"-seeming features of deep neural networks down to earth. The second paper uses an algebra concept called Bezout's theorem to explain how these networks can be successfully trained (or "optimized") using what conventional statistics practices would deem to be low-quality data; the third explains why deep-learning systems, once trained, are able to make relatively accurate predictions about data they haven't been exposed to before using a method that Poggio likens to a machine-learning version of Occam's razor (the philosophical principle that states that simpler explanations for a phenomenon are more likely to be true than complicated ones).

For Poggio, the implications of these theories raise "some interesting philosophical questions" about the similarities between our own brains and the deep neural networks that "crudely" (in his words) model them. The fact that both deep-learning networks and our own cognitive machinery seem to "prefer" processing compositional functions, for example, strikes Poggio as more than mere coincidence. "For certain problems like vision, it's kind of obvious that you can recognize objects and then put them together in a scene," he says. "Text and speech have this structure, too. You have letters, you have words, then you compose words in sentences, sentences in paragraphs, and so on. Compositionality is what language is." If deep neural networks and our own brains are "wired up" in similar ways, Poggio says, "then you would expect our brains to do well with problems that are compositional"—just as deep-learning systems do.

Can a working theory of deep neural networks begin to crack the puzzle of intelligence itself? "Success stories in this area are not that many," admits Rosasco. "But Tommy [Poggio] is older and braver than me, so I decided, 'Yeah, I'll follow him into it.'" Speaking for himself, Poggio certainly sounds like an enthusiastic pioneer. "You want a theory for two reasons," he asserts. "One is basic curiosity: *Why does it work?* The second reason is hope: that it can tell you where to go next." —John Pavlus

The fact that both deep-learning networks and our own cognitive machinery seem to "prefer" processing compositional functions strikes Poggio as more than mere coincidence.

LEARN MORE

See page 35 for news about the MIT Intelligence Quest, a major new initiative at the intersection of human and artificial intelligence.

Breaking the Bottleneck in Genetic Engineering

An Engine-backed startup harnesses microfluidics to reprogram cells with unprecedented speed

If the genetic revolution has yet to deliver fully on its promise, Cullen Buie, associate professor of mechanical engineering, may know one reason why: "In the last 30 to 40 years, our ability to innovate with the genetic code has gotten faster and cheaper, whether reading or writing DNA," he says. "But it's kind of a dirty secret that for decades there's been virtually no innovation in the methods for putting DNA into cells to reprogram them."

This state of affairs may be about to change. Buie and research scientist Paulo Garcia have developed a platform that simplifies and accelerates the process of introducing DNA or other molecules into cells. This new technology may well break the bottleneck in genetic engineering, vastly improving the process of drug discovery and opening up new frontiers in synthetic biology. "Our vision is to make delivery of foreign media into cells faster and easier for all applications," says Buie.

To realize this vision, Buie and Garcia recently formed a company called Kytopen, one of seven startups to receive seed money from MIT's newly minted "tough tech" accelerator, The Engine. Dedicated to supporting innovative ventures with potential for societal impact, The Engine seeks out startups whose breakthrough ideas require time to commercialize.

The heart of the Kytopen platform is an ingenious twist on electroporation—the process of shocking individual cells with tiny amounts of electrical current to open their pores, which permits the introduction of customized DNA or other media. Typically, this process is accomplished by hand, in small batches, with technicians adjusting the current to find just the right amount of juice for zapping the cell open without killing it.

Building on expertise devising microfluidics tools for use in small-scale biological systems, Buie's lab invented a tiny pipette equipped with electrodes through which cells flow. As cells move through the pipette's tiny channel, they are exposed to an electric field with just the right amount of current to open their pores. "So now we can continuously flow cells and deliver DNA into them for reprogramming at a rate that is 10,000 times faster than current state-of-the-art industrial technology," says Buie.

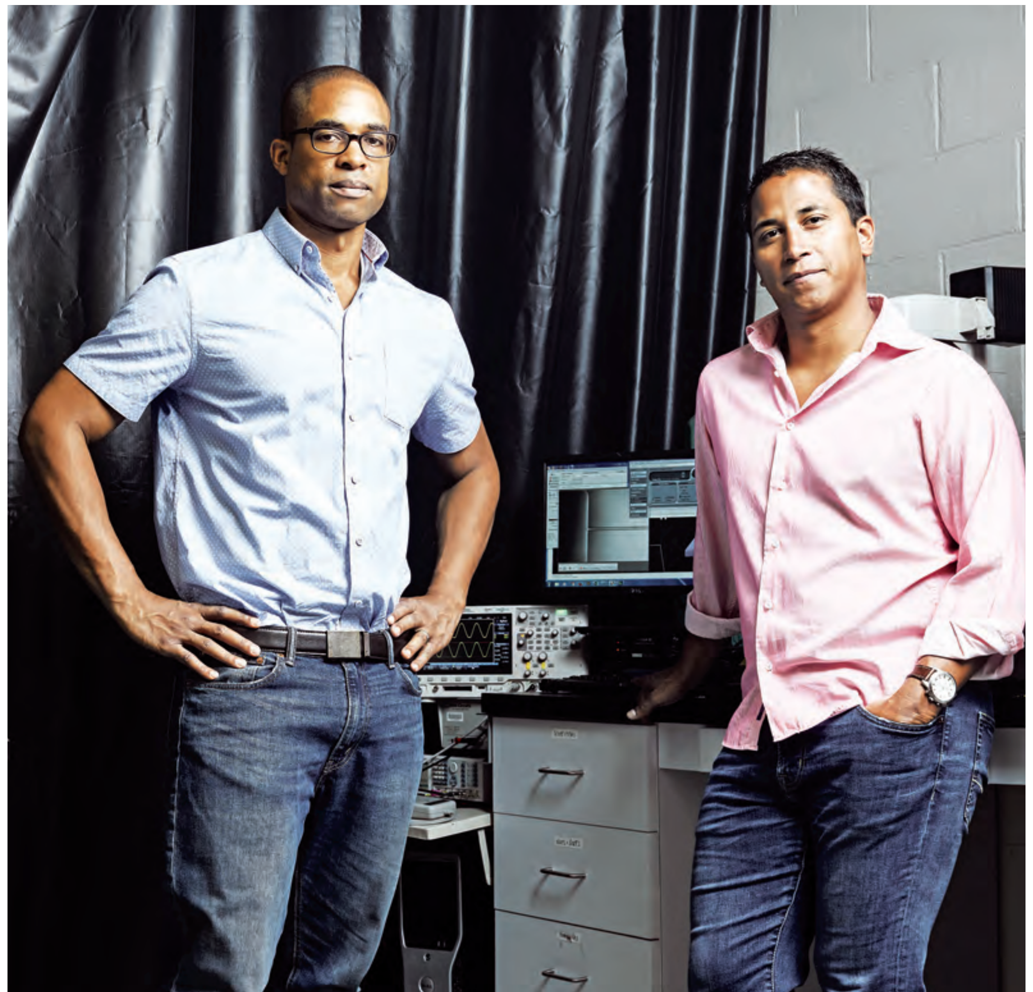
The idea is to scale up the Kytopen platform for high-throughput, high-volume assembly line work, with legions of fluid-handling robots modifying vast batches of cells. For researchers seeking to identify useful new properties in microorganisms or to modify microbes for the purposes of creating novel molecules, this kind of mechanization would prove invaluable.

"The scientific community has characterized maybe 1% of bacteria on the planet, and we've been able to exploit only 1% of that for genetic engineering, so there's a tremendous amount of biological diversity we have yet to harness," says Buie. "Testing DNA sequences and designing nucleic acid to generate a product of interest requires you to make many iterations, and Kytopen could really move things along," he says.

In addition to ferreting out a treasure trove of DNA in microbes that could help develop new drugs or energy technologies, says Buie, the Kytopen platform could also quicken the pace of synthetic biology, facilitating the repair of harmful genetic defects or the creation of bioengineered parts for medicine.

For Buie, the notion of lowering barriers for the discovery and creation of important new applications is energizing. "Before coming to MIT, I thought carefully about areas likely to have a huge impact on society in my lifetime," he says. "Clearly engineering of biology would play a major role in our generation's technological problems and solutions, and I wanted to get into it."

The next phase for Kytopen, says Buie, involves choosing "a killer application that is so well suited for our technology that it is clearly the best solution," he says. As a first-time entrepreneur, he's nervous, but excited. "There's a lot of moving parts, and while we have a vision and a goal, we don't know how it will turn out," he says. "But I've gotten used to working with uncertainty." —Leda Zimmerman



Kytopen, formed by Cullen Buie, left, and Paulo Garcia, is one of the first startups to receive seed funding from The Engine.

PHOTO: COURTESY OF THE ENGINE

When Aniceto visited the Philippines, she saw how providing internet access via satellite network might help impoverished children who can't attend school.

Laser Focus

A broad foundation in space systems helped grad student Raichelle Aniceto zero in on a social mission

Sometime this year, Raichelle Aniceto '16, SM '17 and her labmates plan to send up a satellite payload that will shoot lasers at the Earth. If the beams hit the right spot, they could bring scientists one step closer to achieving rapid communication across deep space and providing internet via satellite network for communities that lack telecommunications infrastructure on the ground. This pioneering effort is an early attempt to transmit data from a satellite using optical communications—sending information encoded in light—rather than radio frequencies. While the concept is not a new one, doing it in space means navigating a web of intertwined variables and limitations, from the weight of the satellite to the clouds that would block the lasers and the harsh radiation of space. And that's exactly why Aniceto likes it.

Now a first-year doctoral student of space systems engineering, Aniceto recalls arriving at MIT in search of a field that was "a touch of everything." That's just what she got when she joined associate professor Kerri Cahoy's Space Telecommunications, Astronomy and Radiation (STAR) Lab in the Department of Aeronautics and Astronautics as an undergraduate research assistant.

As a freshman, Aniceto started out machining test parts for a CubeSat that was later launched by NASA. She was quick to volunteer for any new task and over the next few years branched out into other areas of satellite engineering. She learned how to model the space environment and perform environmental tests on satellite systems, and also helped design a CubeSat for a lunar mission. A growing passion for communication satellites became something of an internet-connectivity mission when Aniceto visited the Philippines, her parents' home country. There she saw how internet access might help impoverished children who can't attend school for logistical or financial reasons.

"If kids have internet," she says, and therefore access to free online videos and courses, "it's a way for them to be able to sit down and teach themselves."

Opting to return to MIT after graduation to continue work with Cahoy (who now holds the Rockwell International Career Development Chair), Aniceto joined a team developing an experimental optical communications system for a CubeSat expected to launch this year. She is also doing optical communications research sponsored by Facebook Connectivity Lab, which aims to provide affordable global internet access through high-altitude drones.

Beaming information from a satellite to a receiver on Earth with a laser, as the STAR Lab's system is designed to do, would allow for much greater data transfer rates than are possible with traditionally used radio frequencies. But with every benefit comes a tradeoff: the narrow beam is more secure, but needs to be pointed very precisely in order to hit a receiver on the ground. Lasers aren't regulated the way radio frequencies are, but they have to be amplified to reach Earth and can't penetrate clouds. On top of this, Aniceto's optical communications system will need to fit inside a satellite about the size of a loaf of bread; it must be light and energy efficient and not generate too much heat, but also be able to withstand the vibration of launch and the radiation of space.

In this tangle of challenges, Aniceto is focused on understanding the effects of radiation on system components. Her goal is to design optical communication systems as inexpensively as possible by identifying commercial off-the-shelf parts that can withstand the expected radiation of a given mission. She says a system might use 50 or so electronic parts, and each qualified, radiation-resistant part might cost a few hundred dollars. So, she's systematically testing cheaper alternatives. First, she runs a computer simulation of the mission in question to determine the expected types and amount of radiation the satellite will experience, then calibrates a radiation chamber to match those conditions and radiates the part. This work builds on her master's research and places Aniceto at the intersection of the fields of optical communications and radiation effects.

"I haven't really met people that are at the bridge of those two yet, besides myself," she says. But she doesn't seem to mind.

"I love the puzzle," she says with a smile.

—Robin Kazmier SM'17

Grad student Raichelle Aniceto began her work in Kerri Cahoy's STAR Lab as an undergraduate.

PHOTO: IAN MACLELLAN

MIT Premieres Its First Facility Dedicated to Performing Arts

"One of our oldest dreams is coming true," celebrated violist and longtime MIT faculty member Marcus Thompson told an audience assembled in November to celebrate the opening of W97, MIT's new performing arts building at 345 Vassar Street. From his vantage point of four decades teaching music performance at MIT, Thompson declared, "It's hard to describe the thrill of the MIT performing arts now having our own 'lab' where we can experiment, collaborate, rehearse—and share our creation and innovation with the MIT community and the wider world."

Student enrollment in theater arts has doubled since 2012, and Course 21M (Music and Theater Arts) draws the fifth-largest enrollment of any course at MIT—yet MIT's theater program was, until recently, scattered across several buildings. Now the program has a dedicated home in Building W97, a gut-renovated warehouse that contains a 180-seat tech-friendly blackbox theater, costume and scene design shops, dressing rooms, and studios for classes that enable experiments with theater technology.

"There is a great focus at MIT on innovation and experimentation in all the technical and scientific areas, and our students also want and need to know about the comparable range of exciting innovation, research, and experimentation in the arts," says theater artist and senior lecturer Anna Kohler, who directed the space's inaugural production, *Everybody*, by Branden Jacobs-Jenkins.

W97 is a milestone in MIT's commitment to invest in the artistic endeavors of its community with spaces that, in the words of President L. Rafael Reif, "live up to the quality of their creativity." MIT is also planning to centralize its thriving music program in a West Campus building. Containing a small performance venue, rehearsal and practice spaces, and administrative offices, the new music building will enable students and faculty to better explore the fertile intersection of music, technology, science, and linguistics.

"For so many students," Thompson said in 2015 on the occasion of his appointment to the highest faculty honor of Institute Professor, "the serious study of music is an integral part of Institute life.... Our students are very drawn to it, they're very good at it, and it becomes part of their lifelong learning."

Above and at right: in November, Branden Jacobs-Jenkins's *Everybody*—the first MIT theater production to be designed, rehearsed, built, and staged in W97's purpose-built space—took advantage of the venue's flexibility and technical capabilities.

PHOTOS: T. CHARLES ERICKSON

Fundraising Update: MIT Campaign for a Better World

At the launch of the MIT Campaign for a Better World in May 2016, President L. Rafael Reif called upon the Institute's alumni and friends to join MIT in its effort to raise $5 billion to take on some of humanity's most urgent global challenges. Propelled by strong support for the Campaign, the Institute ended fiscal year 2017 in June with $589 million in new gifts and pledges, amounting to the highest annual fundraising total in MIT's history. As of January 2018, $4 billion had been raised in the Campaign from more than 91,000 individuals and organizations.

"We are extremely grateful for this show of confidence in MIT," says Julie A. Lucas, MIT's vice president for resource development. "We are particularly thankful to our leadership volunteers, who are dedicating their time and wisdom to helping us realize our vision. It will take the entire community continuing to come together to meet our ambitious financial goal and fulfill our bold aspirations for MIT and what it can contribute to the world."

91,000 supporters = $4B

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The MIT Intelligence Quest

New Institute-wide initiative will advance human and machine intelligence research

An extended version of this story appeared on MIT News on February 1, 2018.

MIT has announced the launch of the MIT Intelligence Quest (MIT IQ), an initiative to discover the foundations of human intelligence and drive the development of technological tools that can positively influence virtually every aspect of society.

"Today we set out to answer two big questions," President L. Rafael Reif said in the February 1 announcement. "How does human intelligence work, in engineering terms? And how can we use that deep grasp of human intelligence to build wiser and more useful machines, to the benefit of society?"

MIT is poised to lead this work through two linked entities within MIT IQ. One of them, "The Core," will advance the science and engineering of both human and machine intelligence. A key output of this work will be machine-learning algorithms. At the same time, MIT IQ seeks to advance our understanding of human intelligence by using insights from computer science.

The second entity, "The Bridge," will be dedicated to the application of MIT discoveries in natural and artificial intelligence to all disciplines, and it will host state-of-the-art tools from industry and research labs worldwide. The Bridge will provide a variety of assets to the MIT community, including intelligence technologies, platforms, and infrastructure; education for students, faculty, and staff about AI tools; rich and unique data sets; technical support; and specialized hardware.

MIT IQ researchers will also investigate the societal and ethical implications of advanced analytical and predictive tools. There are already active projects and groups at the Institute investigating autonomous systems, media and information quality, labor markets and the work of the future, innovation and the digital economy, and the role of AI in the legal system.

MIT has been on the frontier of intelligence research since the 1950s, and now has over 200 principal investigators whose research bears directly on intelligence. Researchers at MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) and its Department of Brain and Cognitive Sciences (BCS) collaborate on a range of projects. MIT is also home to the National Science Foundation–funded Center for Brains, Minds and Machines (CBMM).

MIT IQ will create an organization to 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. Faculty from across the Institute will participate in MIT IQ, including researchers in the Media Lab, the Operations Research Center, the Institute for Data, Systems, and Society, and all five of MIT's schools.

In order to power MIT IQ and achieve results that are consistent with its ambitions, the Institute will raise financial support through corporate sponsorship and philanthropic giving.

MIT IQ will build on the model that was established with the MIT–IBM Watson AI Lab, which was announced in September 2017 and which will be a vital part of the new initiative. MIT researchers will collaborate with each other and with industry on challenges that range in scale from the very broad to the very specific.

"Our quest is meant to power world-changing possibilities," says Anantha Chandrakasan, dean of the MIT School of Engineering and Vannevar Bush Professor of Electrical Engineering and Computer Science. Chandrakasan, in collaboration with Provost Martin Schmidt and all four of MIT's other school deans, has led the development and establishment of MIT IQ.

"We imagine preventing deaths from cancer by using deep learning for early detection and personalized treatment," Chandrakasan continues. "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." —Peter Dizikes, MIT News

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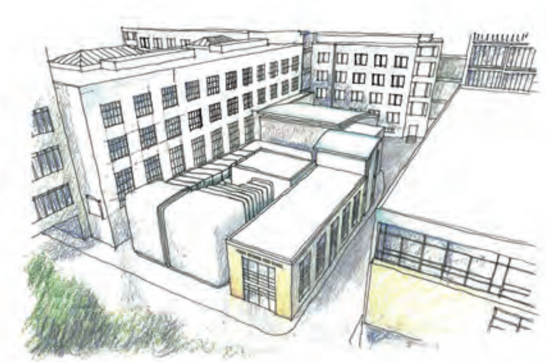
MIT to Construct New Wright Brothers Wind Tunnel

MIT has announced it will replace its 79-year-old Wright Brothers Wind Tunnel with a new facility that will be the largest and most advanced academic wind tunnel in the US. Boeing has made a funding pledge to become the $18 million project's lead donor, reflecting a century-long relationship between the company and MIT that helped ignite the global aerospace industry.

Dedicated in 1938, the current tunnel was in heavy use for the design of military aircraft during World War II. Since then, the tunnel has been used to test everything from subway station entrances to solar cars—and, most recently, a design for a clean, quiet, super-efficient commercial aircraft.

Like its predecessor, the new tunnel will be operated by the MIT Department of Aeronautics and Astronautics, and it will retain the Wright Brothers Wind Tunnel name. The new tunnel will permit increased test speeds, from the current 150 miles per hour to 200 miles per hour; greatly improve research data acquisition; halve the power requirements of the original fan motor; increase test section volume; improve the ability to test drones and aerodynamic components including wings, bodies, and wind turbines; and enable new MIT classes in advanced aerodynamics and fluid mechanics.



The new Wright Brothers Wind Tunnel will be situated in the same location as its predecessor.

IMAGE: COURTESY OF IMAI KELLER MOORE ARCHITECTS

HEMANT '97, MENG '99 AND JESSICA TANEJA

Education Meets Innovation


PHOTO: CHRISTOPHE TESTI

When Hemant Taneja '97, MEng '99 was in high school, his parents moved the family from India to Boston to give him and his sister a better chance at success. "We were the classic immigrant family and had the proverbial American dream," Hemant recalls. "Work hard, study hard, do your best, and rise up in the world. That was a very consistent and nonnegotiable theme in our family."

In that vein, Hemant came to MIT to prepare for a career in education, ultimately earning an impressive three undergraduate and two graduate degrees from the Institute. But Hemant's experience at MIT was transformative, and he emerged set on a new path—that of venture capitalist. Hemant notes that MIT taught him the core skill of systems thinking. "Being naturally curious about many different disciplines and getting degrees in those disciplines was great training," he adds, "because it gave me a unique lens on different types of innovations that are becoming commercial."

Hemant has been in the VC field for 15 years, currently serving as managing director of venture capital firm General Catalyst, where he concentrates on early-stage technology companies. Today Hemant and his wife Jessica find themselves at a point where they can give back in a substantial way.

The Tanejas recently gave a generous gift in support of MIT.nano, the new center for nanoscience and nanotechnology rising up in the heart of the MIT campus. Open to the entire MIT community of faculty, researchers, and students, MIT.nano will serve as a cutting-edge facility designed to nurture widespread, cross-disciplinary research and invention. MIT.nano will also become a training ground for the next generation of science and leadership: classroom and learning spaces with advanced teaching tools will be integrated throughout the building.

Named for Hemant's parents, the Shiv and Santosh Taneja Innovation Alcove will serve as a collaborative breakout space within the new building for cross-disciplinary collaborative work. "The opportunity for me to attend MIT is really what transformed our lives, and eventually our kids' lives, and so I wanted to recognize that and make the gift in my parents' honor," says Hemant.

The Tanejas' decision to support MIT.nano was inspired by their conviction that MIT is doing "profound" work in nanotechnology across many different industries and fields, pursuing solutions for some of the most pressing issues of the time. The gift is also part of the Tanejas' larger philanthropic strategy. "We both wanted to be highly supportive of education and started narrowing it down to where we could have the most impact and benefit," explains Jessica. In that spirit, the Tanejas also helped build the Khan Lab School—founded in California by MIT alumnus Sal Khan '98, MEng '98—which uses the MIT systems thinking approach for elementary education.

Now based in the San Francisco Bay Area with their three children, Hemant and Jessica remain deeply connected to MIT. Hemant returns to the MIT campus often to meet with faculty and students to get a deeper understanding of leading innovations in artificial intelligence, energy, and cognitive sciences. But even living in California, MIT is never far away. "Some of the most successful companies I've invested in have been founded by folks that got their education at MIT," says Hemant. "It's been phenomenal to actively be part of the MIT community in my day-to-day work." –Katy Downey

CAROLINE HUANG SM '85, PHD '91 AND MIKE PHILLIPS

Rooted in Personal History, a Gift for Today's Students


PHOTO: M. SCOTT BRAUER

For Caroline Huang SM '85, PhD '91 and Mike Phillips of Belmont, Massachusetts, MIT is closely linked to family, both past and present. Their paths intersected in 1987 at MIT's Department of Electrical Engineering and Computer Science (EECS), where Caroline was a doctoral student in speech communication, and Mike was a researcher in the Research Laboratory of Electronics (RLE). In 2012, they created the Huang Phillips Fellowship for first-year graduate students in EECS to honor their MIT roots and, in Caroline's words, "support a new generation of MIT scholars."

In Caroline's childhood home, MIT was considered "the best engineering and science university in the world." Her father, Thomas Shi-Tao Huang SM '60, ScD '63, was born in Shanghai. While earning his BS in electronics at the National Taiwan University, he wrote to famed MIT electrical engineer Ernst Guillemin '24 about a math problem he'd encountered in one of Guillemin's books. Recognizing the young man's talent, Guillemin encouraged him to apply to MIT. Thomas S. Huang went on to become one of the world's leading scholars in computer vision, pattern recognition, and human computer interaction. Recently retired from the University of Illinois at Urbana-Champaign, he remains active as a researcher and academic advisor. Three of his four children earned MIT degrees, including Caroline, who studied acoustic phonetics with the late Kenneth Stevens ScD '52, Clarence J. LeBel Professor Emeritus in EECS.

"I remember that time in my life very fondly," says Caroline. "Our research group, which included people from around the world, forged lifelong friendships and professional relationships." She credits MIT with helping her acquire invaluable technical and analytical abilities, and essential non-technical skills, like teamwork and collegiality. She remembers Stevens, who died in 2013, as "brilliant, kind, and very generous." After MIT, she worked on speech recognition in industry, and currently divides her time between consulting, volunteering, and engagement in the lives of her and Mike's two sons, ages 17 and 21.

Mike came to MIT from Carnegie Mellon, where he completed his undergraduate degree. After seven years as a research scientist in the Spoken Language Systems Group led by Victor W. Zue ScD '76, Mike founded several successful companies, including SpeechWorks, where he led the development of speech recognition technology for automated call centers ("We apologize for that," he adds, tongue-in-cheek) and Vlingo, which developed a speech interface for cellular phones used by Samsung, Nokia, and Blackberry. His present company, Sense, applies machine learning techniques to the challenge of home energy efficiency. His experience illustrates MIT's impact on entrepreneurship: "As a young researcher, I had no clue about starting a company. Then I reached out to one of MIT's entrepreneurship programs, and began making great connections and learning about licensing MIT technology. That was an amazing experience. It was a natural decision to give back."

Caroline and Mike hope to provide others with the lasting benefits they have enjoyed through MIT, and to help MIT remain a global beacon of learning and opportunity, as it was for Thomas S. Huang. As Caroline puts it, "This is a way I can honor people like my father, who are entering an exciting new program of study when they come to MIT, and perhaps also a new country and a new life." –Kris Willcox

Next Stops on the Better World Tour

Alumni and friends are invited to attend regional events celebrating MIT, our vibrant global community, and our mission to build a better world. Already, President L. Rafael Reif has shared his vision for the future of MIT at gatherings in New York, San Francisco, Hong Kong, London, Tel Aviv, Los Angeles, Mexico City, Washington, DC, Boston, and Houston.

The tour continues this winter, with two events produced in partnership with MIT Sloan School of Management:

2.20.18 / Benaroya Hall

Seattle

3.8.18 / Alfred I. duPont Building

Miami

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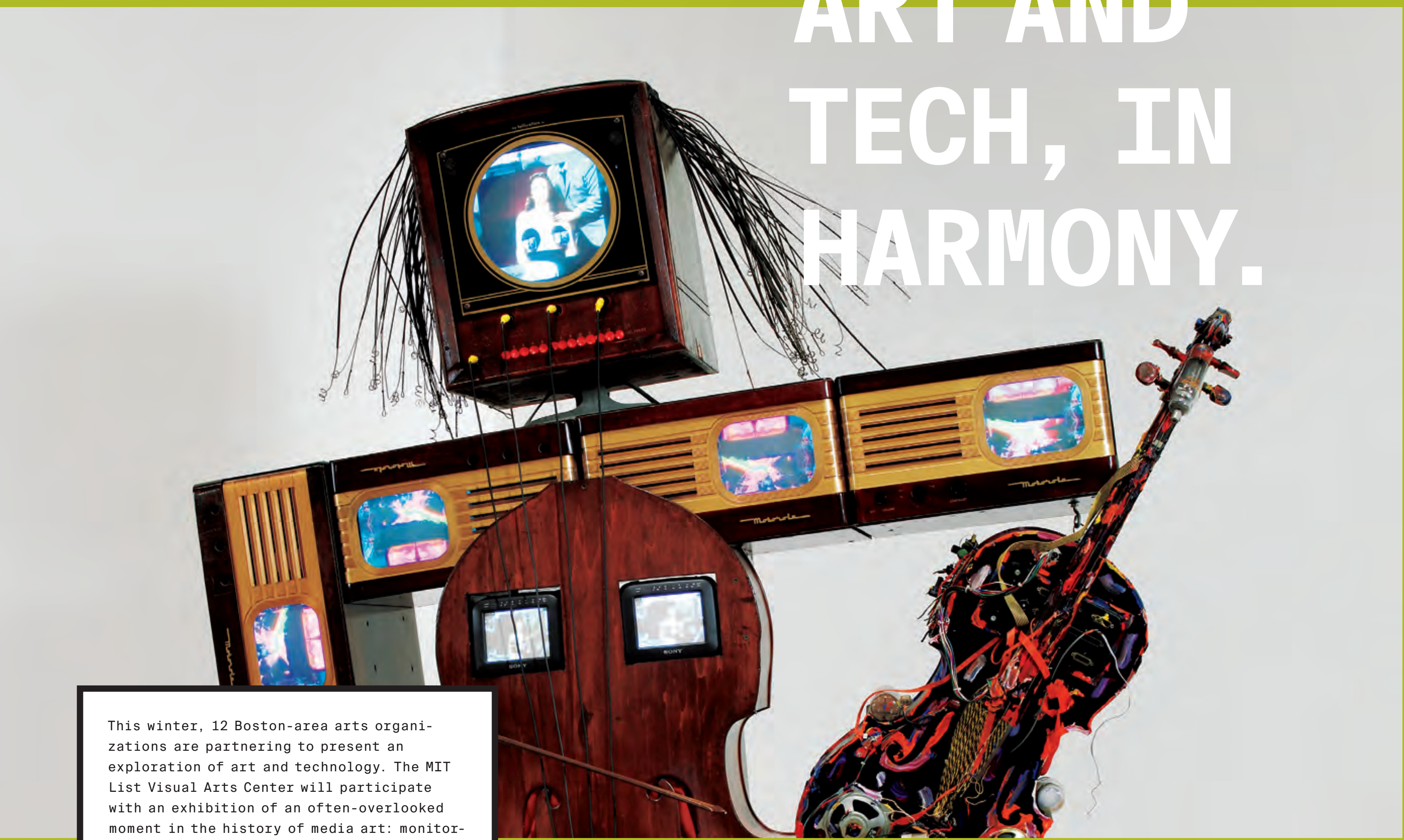

This winter, 12 Boston-area arts organizations are partnering to present an exploration of art and technology. The MIT List Visual Arts Center will participate with an exhibition of an often-overlooked moment in the history of media art: monitor-based installation. Included is a sculpture by Nam June Paik of his frequent collaborator, cellist Charlotte Moorman, which points to another art/tech link: both were fellows at the MIT Center for Advanced Visual Studies (see page 3).

CAMPAIGN FOR A BETTER WORLD