INTRODUCING
THE MIT
INTELLIGENCE
QUEST
P. 35

PATHWAYS ➔ POLICY
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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. From research that informs new ones, for the betterment of humankind.

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.

From Research to Policy

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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 100 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 peace time. At that time, Kepes was best known as a member 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 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 this fall. ACT will also sponsor a series of campus-wide events and exhibits in honor of the anniversary this spring.

A Radical Meeting of Art and Science

1967: Kepes establishes CAVS, which moves into a renovated Building W11 at 48 Massachusetts Avenue.

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

1977: Germany “documenta 6” exhibition commission from CAVS one of its most ambitious undertakings: Dermonia, a massive kinetic sculpture created over a one-year period at the Botanical Hall.

1980s: MIT Visual Arts Program (VAP) is founded within the Department of Architecture by Professor Ed Sciolino and its graduate program is launched.

1988: Keiko Otani accepts an invitation from MIT’s School of Architecture and Planning to teach visual design.

1988: Picture: CAVS Fellow Yasuaki Takii’s electromagnetic sculpture Antigravity

1989: The MIT Media Lab is founded.

1994: By the end of the two decades at CAVS, conceptual artist Larry Burgess has created the first actual prototypes to be cast into outer space by NASA.

1995: ACT Professor Emeritus Joao Jonas is in the US representing the Mexico Biannual with a new solo show, They Come to Us without a Voice, organized by the MIT List Visual Arts Center.

2015: ACT Professor Emeritus Joao Jonas is in the US representing the Mexico Biannual with a new solo show, They Come to Us without a Voice, organized by the MIT List Visual Arts Center.

2018: Alongside Jonas and new ACT director Seth Hasty, ACT’s Faculty includes Arzu Aksanlioglu, PhD (11), Anna Green, and Gedeona Ustian. Eleven graduate students are working toward a Masters of Science in Art, Culture and Technology (SMAC) and 160 undergrad and grad students enrolled in ACT courses in Fall 2017.
Space Detectives

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

THE INSPIRATION

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 melten 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 1991), 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.

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 advisor, either through the FAS program or one-on-one mentoring.

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.

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 has written in a planet’s interior and create their own magma.

Curriculum: Winter 2018

<table>
<thead>
<tr>
<th>WEEK</th>
<th>Topic</th>
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<tbody>
<tr>
<td>1</td>
<td>Learn about meteorites and geological origins of Mars</td>
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<tr>
<td>2</td>
<td>Discuss theories 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 mentors every year well enough that the professors could write them a letter.</td>
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<tr>
<td>3</td>
<td>Learn about the asteroid belt and the meteorites that come from there</td>
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<tr>
<td>4</td>
<td>Study theories for the formation of inner rocky planets</td>
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<tr>
<td>5</td>
<td>Discuss theories about why and how the moon began orbiting the Earth</td>
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<tr>
<td>6</td>
<td>Understand what we can infer about Martian planetary history from Martian meteorites and the geological formations on Mars</td>
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<tr>
<td>7</td>
<td>Explore the geology of the moon</td>
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<tr>
<td>8</td>
<td>Learn about Mercury from images and information gathered by the Mercury Messenger</td>
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<tr>
<td>9</td>
<td>Study the formation of other star systems</td>
</tr>
<tr>
<td>10</td>
<td>Watch science fiction movies that feature planetary science</td>
</tr>
<tr>
<td>11</td>
<td>Make magmas</td>
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</tbody>
</table>

Associate advisor Sarah Webster London ’18: “I like the low-key, the class isn’t high-pressure, it’s nostalgic being with freshmen.”

Grove: “The course’s name intrigued my interest, as well as planetary formation and geology.”

Megan Guenther ’21: “The course is fun and hands-on, and we get to make our own meteorites. It’s a really unique experience.”

Hannah Michaye ’20: “I like the group dynamic. There are one or two faculty mentors to help us understand how we can get through MIT and more experienced students. I love all the course work. The professors could write a letter to the students.”

Ledford ’20: “I like how we get to know other students. I love the opportunity to do a great job of breaking down the barrier between professors and students. I like being able to brag to my classmates that my advisor has an asteroid named after him.”

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

PHOTO: SARAH BASTILLE

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

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.”

Grove: “We talk about how the hydrogen in your body is 1.2 billion years old and how we’re all made of stardust.”

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

SARAH BASTILLE

spectrum.mit.edu
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.
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 unequalled 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 issue 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 across the world. J-PAL has more than 850 staff or consultants working in 90 countries.

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 raise 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 60 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 Duflo—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.

GPI has so far awarded $1.8 million for 24 partnerships—from tackling a court backlog in Mexico to implementing educational reforms in Zambia.
In 2000, hanging chads clouded the presidential election between George W. Bush and Al Gore. In 2006, 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) has anything to say about it. Launched in January 2017 and funded 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 2012, 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, develops 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,” says Stewart.
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 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 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 Science and Policy. Kemp’s project concerned 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, 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 academica,’” 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 analytical grounds.”

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

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.Ralph Dorm-Haken Starck Professor of Political Science Suzanne Berger, MIT Sloan Professor of Political Science Robert Goodin, and former MIT President Paul Gray, Seminar XXI is 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 worlds 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; the threat of nuclear proliferation; the human development of cities; and the human memory of environmental change. Seminar XXII 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 Court Justice, and Chief of Staff.

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.”

Sebastian Wolferton is a 2006–07 MIT Knight Science Journalism Fellow.

**Framing Uncertainty**

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

The barrage of hurricanes that in 2017 pummeled the Caribbean islands, United States, and even Ireland—fuelled in part by unusually bolty Atlantic Ocean temperatures—provided a glimpse of consequences that may accompany a warming planet. If left unchecked, climate change will set in a “death-multiplying” increase in 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 and Oceanic Sciences. 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 disentangling the full range of impacts of climate on people and 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 synthesis of the Joint Program, the mission of which is “to provide a sound foundation of scientific knowledge to aid decision makers in confronting the multifaceted risk of climate change.”

Projects like climate change into the future requires an understanding of both the natural environment and of how human development occurs,” explains Ronald Prinn ’73, PhD ’78, TCPG Professor of Atmospheric Science who co-directs the Joint Program with John Rotty, 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 impact?”

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

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

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. Researchers, whose findings are well repre sented in the peer-reviewed scientific literature, continue to launch inquiries that focus on new technologies or highlight specific issues such as climate impacts on water and agriculture.

“Key goal of this undertaking,” says Rotty, “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 a degree Celsius or less. The authors then presented a set of emissions scenarios that could satisfy the degree-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 bioenergy could similarly take up land and water that might otherwise be reserved for growing crops. Obtaining cooling water for power plants also gets harder as river temperatures rise. “It’s becoming more apparent that the 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 MIT Joint Program developed these roulette-wheel tools to convey uncertainty to climate change decision makers. Each shows the estimated probability of potential change in global average surface temperature by 2100, given conditions with and without policies that mitigate emissions.
**Pathways to Policy**

**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 sales, 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 11% and 14% in four 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. 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 worlds, 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.

Hoping 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.”

**Energizing Global Environmental Cooperation**

*How Valerie Karplus and her transpacific colleague 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 1995 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?”

Karpas 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.

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

After earning her doctorate, Karplus became director of MIT-Tsinghua China Energy and Climate Project, a partnership between MIT’s Joint Program on the Science and Policy of Global Change (see page 16) 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 CO2, 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 arguments on both sides were projections that China’s fossil energy usage would climb without a ceiling. In contrast, results from the MIT-Tsinghua model, shared with policy makers in both nations, suggested China’s energy-related CO2 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.”

Karpas 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. “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.

Karpas and her transpacific colleagues have expanded focus beyond policy design to policy implementation. One striking piece 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 enables 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 Blending
At the Intersection
Five grad students on finding their own routes into the policy sphere

Daniel Gilford
PhD candidate, Earth, Atmospheric and Planetary Sciences
Research focus

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 must reduce climate pollutant emissions—so we did with CPICs 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 balancing
“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.”

Rayara 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 who can talk both languages and facilitate 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 one 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 databases on workers and firms is a key step in elucidating complex issues like this.”

Samantha Zyontz ‘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.”

Reed Jordan
Routes 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 grand-father returned from WWII and was rewarded for his service with a generous state 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, Mechanical 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 Biointerfaced 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 tax.”

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 lab 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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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 and Law, was born 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 (IPRI) in 2012. 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 1992 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 and 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.

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.

“After we discovered 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.”

Closely 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.

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.

MIT engineering students team up with Georgetown lawyers-in-training on internet privacy legislation
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 races 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 implying a return to the horizontal. You might even invert 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 these 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?

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 Straw

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. Sweeney to avoid the pedestrian, 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.

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’ve still working up the results but a couple of things are clear. “Almost every person has something to say...
The need

In 2013, Haiti’s government, through an agreement between the Ministry of Education and the Haiti Creole Academy (of which DeGraff is a founding member), announced that it would make Kreyòl as language of instruction at all levels of the school system. This represents a major break with a tradition whereby French has been the exclusive language of formal education—a tradition that has impeded the learning 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

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 search by issue area (e.g., the Volcker Rule, the Consumer Financial Protection Bureau) or search a handle on policy terms to the Kreyòl module.

The need

In other words, Rahwan believes that artificial intelligence has the power to make us more human, not less. “As Daniel DoB O’Reilly, another of roughly 20 researchers and students in Rahwan’s group, characterized the push to make self-driving cars as "the tragedy of the algorithm 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%.”

To read [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?
5. How can we make modern technologies—specialized tools used correctly, consistently, and safely—benefit all people?

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 emotions.

In other words, Rahwan believes that machines have the power to make us more human, not less.
Each year, the United States spends more than $3,000 per person on health care. Yet the world’s most costly health care system is neither the most effective nor efficient. Citations 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 improving patient outcomes to create a medical system focused on Retsef Levi and colleagues are helping to leverage data through models to inform decisions, particularly 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.

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 MGH’s project to improve hospital performance, 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’re being asked 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 has been to focus on improving patient outcomes, which ultimately lead to lower cost and more efficient systems.” —Ken Shulman

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.

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.

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 13.5 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 177 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

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 for 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 a nonprofit advisor to the President and Congress on matters related to science and education.

Fostering a STEM-capable US workforce that all Americans are prepared to meet evolving workplace demands.
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.
Poggio and Rosasco’s 2018 paper, for example, explains why deep-learning networks can be more effective than their shallow counterparts. They use a mathematical framework called “compositional functions” to prove that deep-learning networks can better approximate complex functions. This is important because it suggests that deep-learning networks can be more effective at tasks like image recognition and natural language processing, which are crucial for many applications, including self-driving cars and virtual assistants.

The implications of Poggio’s work are significant, particularly in the context of AI research. If deep-learning networks can indeed perform better than shallow networks, it opens up new possibilities for AI systems to perform tasks that are currently beyond the capabilities of simpler models. This could lead to breakthroughs in fields like autonomous driving, healthcare, and robotics, where the ability to understand and respond to complex situations is crucial.

However, there are also challenges and limitations to consider. For example, deep-learning networks are still prone to “overfitting,” which means they can become too specialized to a particular dataset and fail to generalize to new data. This is an area of ongoing research and development, with many scientists working to improve the robustness and reliability of deep-learning models.

In conclusion, Poggio’s work represents a significant step forward in our understanding of how deep-learning networks work. By providing a theoretical framework for understanding these networks, his research helps to bridge the gap between the behavior of these systems and our own cognitive machinery. As we continue to develop and apply deep-learning algorithms in a wide range of applications, the insights provided by Poggio’s work will be increasingly important for advancing the field of AI.
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 a 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 DNA 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 “touch tech” accelerator, The Engine. Dedicated to supporting innovative ventures with potential for societal impact, The Engine seeks startups whose breakthrough ideas require time to commercialize.

The heart of the Kytopen platform is an ingenium twist on electropermeation—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 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 new useful 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 constructs 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, and I thought clearly engineering biology would play a major role in our generation’s technological problems and solutions, and I wanted to get into it,” he says.

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. “I’ve gotten used to working with uncertainty.”

Leda Zimmerman

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 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.” But 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.

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“We 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.
"One of our oldest dreams is coming true," celebrated 2016 MIT Campaign Co-Chair and MIT Trustee Stephen C. Angell. "In May, President L. Rafael Reif called upon the Institute's leadership volunteers, who are dedicating their time and wisdom to our leadership volunteers, who are dedicating their time and wisdom to 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.”

"It’s hard to describe the thrill of the MIT performance arts that we are now putting on our own ‘lab’ where we can experiment, collaborate, rehearse—and show 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 51st-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 spaces that enable experiment 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 existing innovation, research, and experimentation in the arts,” says theater artist and senior lecturer Anna Kohler, who directed the space’s inaugural production, Everybody, by Brandon Jacobs-Jenkins.

W97 is a milestone in MIT’s commitment to invest in the arts and the arts endeavors of its faculty to better explore the fertile intersection of music, technology, science, and linguistics.

"The serious study of music is an integral part of music, technology, science, and linguistics. With the MIT community, including intelligence technologies, platforms, and infrastructure; education for students, faculty, and staff about AI tools; and unique data sets; technical; 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 1930s, 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 (CMiM).

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 collaboration since 2021, and its resources will directly support the Institute’s work in MIT 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.

"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?"
Education Meets Innovation

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’, 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.”

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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).