MIT SLOAN

BATTLING CYBERCRIME

MIT TACKLES A GLOBAL CHALLENGE

INSIDE

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Andrew W. Lo presents at the "A Better World is Our Business" event in Boston, MA, April 27, 2017.

DEAR FRIENDS,

At MIT Sloan, we are proud to be MIT's school of management. Studying and teaching management in our uniquely MIT way means that we work together to solve complex problems. We look beyond traditional boundaries and work across disciplines, forming partnerships across campus and with industry to tackle some of the world's most pressing challenges.

In this issue of *MIT Sloan*, we showcase two current examples of such creative collaboration. Our "Innovation at Work" article explores the research of an interdisciplinary team of faculty led by Retsef Levi and Yasheng Huang. Their goal? To make the global food supply chain more secure by developing models to better predict and prevent risks to food safety.

Our feature article, "Battling Cybercrime," looks at how the school's Interdisciplinary Consortium for Improving Critical Infrastructure Cybersecurity—dubbed (IC)[3]—has assembled a cross-Institute team to explore the technical, trade, policy, and managerial implications of cyberattacks. Led by Stuart Madnick, (IC)[3] is working with several teams to explore how better information and a more holistic approach to preventing cyberattacks can help businesses and governments both anticipate and recover from data breaches.

These are just two examples of the critical problems that are especially well-suited to being solved at MIT—where some of the world's brightest minds come together to invent solutions to improve the world.

Sincerely,

David Schmittlein
John C Head III Dean

MIT SLOANSCAPE

JOHN F. KERRY URGES MIT AUDIENCE TO LEAD THE WAY TO A CLEAN ENERGY FUTURE

"No nation will do well sitting on the sidelines choking on the fumes generated by obsolete technologies," says the former secretary of state.

In January, with his days in office waning, U.S. Secretary of State John F. Kerry appealed to the scientists, inventors, and entrepreneurs in the MIT community to aggressively pursue solutions to climate change.

Kerry spoke to an audience of approximately 200 people at the MIT Samberg Conference Center January 20, urging his listeners to work quickly to solve the climate change dilemma regardless of the changing presidential administration.

"The truth is, climate change should not be a partisan issue," Kerry said, noting that glaciers are melting at an unprecedented rate, and sea levels are rising three times faster than they did last century. The past year was the hottest year on record.

Crediting progress at the state and local

> **"The truth is, climate change should not be a partisan issue."**
>
> JOHN F. KERRY

levels around the country, Kerry applauded his home state of Massachusetts, which has solar installations in 350 of its 351 towns. Since 2011, the state's Clean Energy Results Program has advanced environmental protection by developing and promoting renewable energy goals.

Boston will host the third annual U.S.-China Climate Leaders Summit this year. Kerry emphasized that local efforts, including those by Boston Mayor Martin J. Walsh, who was in the audience, will be essential for future progress.

While Kerry said the Paris Agreement, a deal to limit the rise in global temperature reached by 195 countries in 2015, will not be enough to stop climate change on its own, he called it a "clear signal" to the marketplace about the future of energy.

Kerry said that over the last decade, the global energy renewables market has expanded dramatically, and investments in renewable energy reached nearly $350 billion.

He cited President Barack Obama's efforts and said Congress collaborated in an "unusual bipartisan fashion" on tax credits for renewable energy. In 2016, U.S. investment in renewable power generation totaled nearly $33 billion.

Kerry predicted job growth in the clean energy sector would be driven by global market demand, saying that the energy curve is "bending toward sustainability."

"It's not a question of whether we will transition to a new economy. We will," Kerry said. "The question is whether we can accelerate the transition. No nation will do well sitting on the sidelines choking on the fumes generated by obsolete technologies," he said.

—*By Amy MacMillan Bankson*

TALKING TO YOUR BOSS ABOUT DATA

Here's what two MIT business analytics students learned in the new From Analytics to Action class.

One of the biggest challenges in data analytics is presenting results in a way that's meaningful to people who aren't data scientists. As MIT Sloan Master of Business Analytics student Souhail Halaby pointed out, there's a model that shows that the winner of the Super Bowl can predict the next year's stock market performance.

While this is interesting, it's little more than the butterfly effect, Halaby said. "You need human intuition to determine whether the correlation is important," he said.

Halaby, and more than a dozen other students who enrolled in the new master's program, learned how to apply a human touch to mathematical models in a five-day class offered during the Sloan Innovation Period last October. The class, taught by Ray Reagans, the Alfred P. Sloan Professor of Management and professor of organization studies, will be offered to more students and expanded to a half-semester beginning in the fall of 2017.

Here's what students learned in the first version of the class.

'STAKEHOLDERS HAVE TO TRUST YOUR DATA'

In the class, students used the R statistical computing software environment and the Julia dynamic programming language to build a visualization of kidney transplant data. Potential kidneys vary in quality, blood type, and location, and patients awaiting a transplant have to consider their options—accept a kidney now from a donor of average health, or wait longer for a kidney from a healthy donor?

Patients are only one group interested in the results of this model. So, too, are the doctors who treat patients and the hospital executives who want to improve outcomes for transplants. Each of these stakeholders comes to the table with a different point of view and set of expectations for what the model will tell them. But they also bring a level of subject matter expertise that a data scientist does not possess, and they are accustomed to using that expertise—and not a data model—to make a decision.

Business analytics student Afshine Amidi said an important takeaway from the fall class was the importance of a model's interpretability, especially when presenting it to people who do not have a background in data analytics.

"It's important for stakeholders to see what your model is about. What data are you using to produce your result?" Amidi said, adding that storytelling can be an effective way to pique an audience's interest in how a model solves a problem. "Your stakeholders have to trust your data. You have to convince them."

'MAKING THE CASE FOR INNOVATION'

Making that happen requires considering how a model will be adopted and implemented, said Reagans, one of five professors (along with two doctoral students) who taught the class last fall. The other professors were Dimitris Bertsimas, Emilio J. Castilla, Jack Dunn, Roberto M. Fernandez, Thomas Kochan, and Jerry Kung.

"When making the case for their innovation, the students needed to understand how people in an organization are likely to think about the problem the students are solving," Reagans said. Since the typical stakeholder may not be used to thinking about problems in terms of data and algorithms, the class offered insight into addressing and overcoming resistance to behavior change.

One strategy is to build informal networks within an organization in order to improve the odds of getting buy-in for an initiative, Reagans said. Another is to anticipate stakeholders' cognitive biases, such as knee-jerk reactions or the silo effect, and try to overcome them by asking the right questions and establishing a framework for making decisions.

'ANALYTICS IS MORE PEOPLE RELATED'

While mathematical models are nothing new, predictive models powered by machine learning have only emerged in the past few years, Halaby noted. Analytics sits at the intersection of mathematical and predictive models.

Machine learning platforms, such as Google DeepMind and IBM Watson, make it possible to create powerful and accurate models, but they aren't intuitive, Halaby said. "There are layers upon layers of computational code that even a programmer doesn't understand."

The real power is in the ability to run a wide, deep, and up-to-date data set through a simple model such as a linear regression and generate rapid iterations of the same calculation. This will produce descriptions that are "descriptive and intuitive to the people you need to present to," he said.

"Analytics is more people related," Halaby added. "In the real world, there are different players and stakeholders. The implication of that is how you present the data, how you use the mathematical principles to get the results you want."

—By Brian Eastwood

Q+A

HOW EVERYDAY PEOPLE CREATE THE MOST HELPFUL THINGS

In *Free Innovation*, MIT Sloan's Eric von Hippel reveals a world where invention is its own reward.

What do Craigslist and new inventions like the remote glucose monitor Nightscout have in common? They were invented not for financial gain, but to solve a problem for their inventors. More and more, new products and new ideas come not from people developing things for sale, but from individuals creating gadgets and apps around the world for self-rewards. In his new book, *Free Innovation*, MIT Sloan Professor Eric von Hippel outlines a brave new world of invention—one that doesn't run on intellectual property and isn't ruled by the bottom line.

Free Innovation is available as a free download from the MIT Press. A print version is available for purchase. In this new book, von Hippel explains why the pace of innovation by consumers who "give away" their innovations is accelerating and why the process of innovation isn't just a means to an end.

WHO ARE THESE PEOPLE, AND WHY ARE THEY COMING UP WITH THESE NEW PRODUCTS?

My colleagues and I surveyed people in six countries via nationally representative samples. We determined that tens of millions of people spend tens of billions of their own dollars on new designs and devices in just those six countries alone. Free innovation—never previously measured—turns out to be a massive phenomenon.

WHY DO FREE INNOVATORS DO WHAT THEY DO?

The survey research shows that they innovate for self-rewards rather than being motivated by potential payments from others. For example, they are rewarded by solving their own problems. That is a self-reward. Or they are motivated by the fun and learning they gain from the process—again forms of self-reward.

Because they are self-rewarded, they do not need to sell what they create to "pay them back" for their innovative investments. And so, 90 percent of these millions of innovators simply give their innovations away. Only 10 percent decide to be entrepreneurs, protect their designs by intellectual property rights, and seek to profit from sales.

Take, for example, the South African carpenter Richard van As who lost part of his hand in an accident. He reached out to the artist Ivan Owen and together they created a 3D-printed artificial hand that opens and grips as he bends his wrist. The device was radically simpler and cheaper than commercial devices—a few tens of dollars instead of thousands of dollars per unit. They could have patented and sold the design, but instead they converted it to be printable on a personal 3D printer and shared it on the internet for free. Now there's a worldwide network of volunteers called Enabling the Future that downloads the design and prints hands for free for local kids who need them.

FROM THE CAVE TO THE GARAGE, HUMANS HAVE ALWAYS TINKERED TO SOLVE THEIR OWN PROBLEMS. WHY IS FREE INNOVATION TAKING OFF NOW?

It's certainly getting stronger because of computerization and the internet. The internet makes communication between people easier, and design tools like [computer-aided design] make it cheaper to do at home and easier to coordinate with others. The free innovation paradigm has grown up. It's the biggest challenge to the long-established pattern of commercial innovation since the Industrial Revolution. Still, as I write in chapter seven of my new book, producers can also benefit from free innovation by commercializing designs free innovators have created. As a form of giving back, they can also give free tools to support their work. A good example is the computer game producer Valve. That firm offers free tools and support via a website for consumer innovators called Steam Workshop.

WHERE IS FREE INNOVATION HEADED?

Free innovation is now being studied intensively by academics around the world. My colleagues and I have formed the Open and User Innovation Society to support this effort. Collectively, hundreds of academics are working to make free innovation and the "free innovation paradigm" better understood as a major complement to the standard producer innovation paradigm. Both are important and useful, and as we learn how to make them function better together, human creativity, business, and social welfare will all benefit.

—*By Jill Maxwell*

> **Free innovation … turns out to be a massive phenomenon."**
>
> ERIC VON HIPPEL

FREE INNOVATION
Eric von Hippel

VOLUNTEER SPOTLIGHT

NAME: **Sarah Kalloch**
PROGRAM & YEAR: MBA '16
VOLUNTEER POSITION:
Reunion Committee/Sloan 5 Boston

FAVORITE MIT SLOAN MEMORY:
Too many to list! I loved every second of my time at Sloan. From trekking through Myanmar to living in Medellin for a month helping a company create a supplier sustainability strategy, Sloan exposed me to new ideas, beautiful places, and brilliant people.

WHY I VOLUNTEER: I want to give back to organizations that improve the world—which is Sloan's mission. This community is overflowing with leaders who are making the world a better place, from energy innovation to cybersecurity to supply chains to impact investing to good jobs and so much more. Creating ways for this amazing group to connect and reflect and support each other is a fun way to have impact on the intuition I love, and, more broadly, on the planet.

FAVORITE VOLUNTEER MEMORY:
The 2016 Class Gift Committee made several music videos to encourage our classmates to give—filming those was a riot. (You can view them at www.youtube.com/watch?v=STDSzGYFmgA and www.youtube.com/watch?v=R1p0-Wg2IoI.) And I'm looking forward to making more memories at our first reunion in June!

SOCIAL MEDIA SPOTLIGHT

Did you know that the MIT Sloan Alumni social media accounts can keep you connected to the school no matter where you are?

In addition to daily posts featuring school and program news, faculty research, and thought-provoking intellectual content, the MIT Sloan Alumni social media channels provide live coverage of MIT Sloan Office of External Relations-sponsored conferences and Reunion Weekend.

If you are unable to attend one of our events, make sure to follow us on Facebook, Twitter, Instagram, and Snapchat, as we bring the cutting-edge research and groundbreaking ideas presented at events and conferences straight to you.

Check out what our social media channels have covered so far this academic year:

MIT Health Innovations #MITSloanHSI

50th Anniversary of MIT Entrepreneurship #MITeship

FinTech and the Disruption of Finance #MITFinTech

A Better World Is Our Business #MITBetterWorld
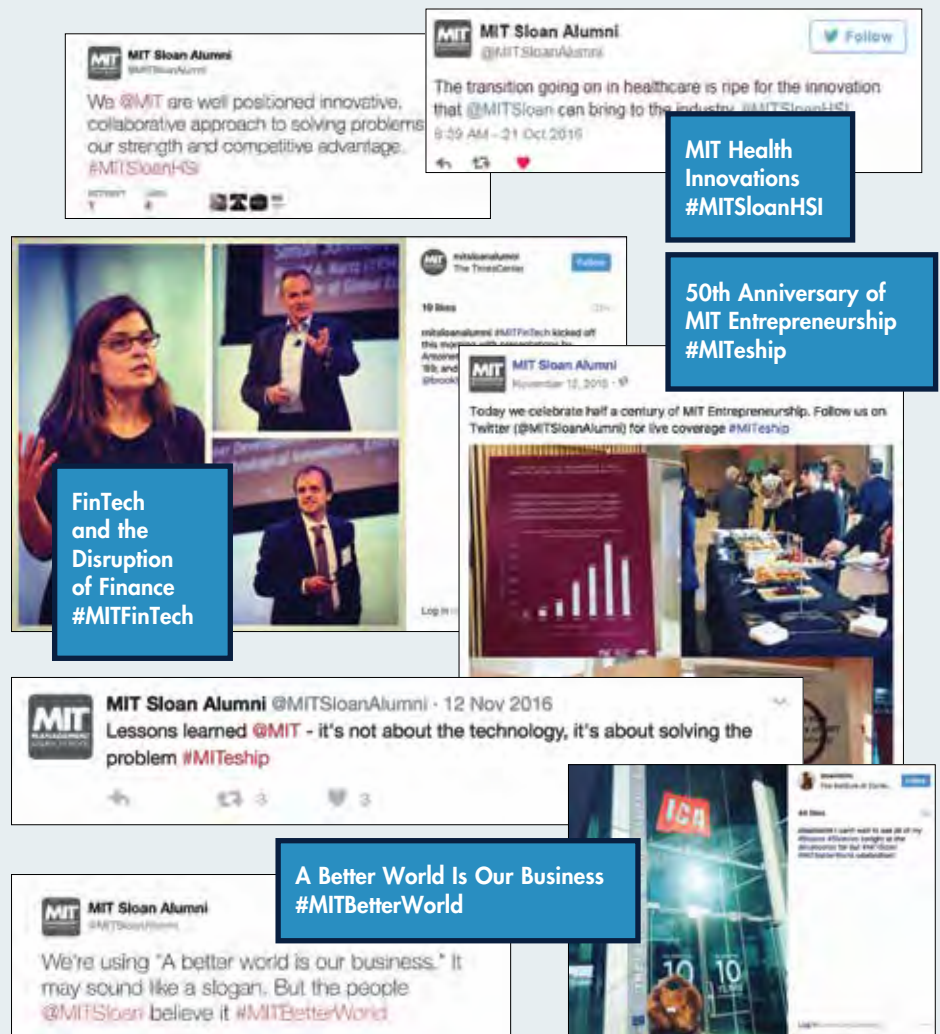
For complete social media recaps of all our conferences and events, visit storify.com/mitsloanalumni

**MITSloanAlumni
mitsloan.mit.edu/alumni/get-involved/social-media-hub**

PROFESSOR STEPHEN A. ROSS, INVENTOR OF ARBITRAGE PRICING THEORY, DIES AT 73

Ross, who joined MIT Sloan in 1997, relished the practical use of finance theory.

MIT Sloan Professor Stephen A. Ross, inventor of the arbitrage pricing theory and a foundational member of the practice of modern finance, died Friday, March 3, 2017. He was 73.

Ross, the Franco Modigliani Professor of Financial Economics, was best known for his arbitrage pricing theory, developed in 1976. The theory, commonly known as APT, is used to identify and exploit mispriced assets by tracking a number of macroeconomic factors. It serves as a framework for analyzing risks and returns. The APT is widely applied in investment management practice today. Ross is also responsible for the economic theory of agency and was the co-creator of the Cox-Ingersoll-Ross model of pricing government bonds and the binomial model for pricing options.

Those theories and models are cornerstones of neoclassical finance, a field which Ross pioneered and defended in a 2004 book of the same name. MIT Sloan Professor Leonid Kogan, a former student, co-authored the behavioral economics-based "The Price Impact and Survival of Irrational Traders" in the *Journal of Finance* with Ross in 2006.

"Steve was a scholar. If the model tells you otherwise and the results go against his beliefs, he updates his beliefs," Kogan said. "His main position wasn't dogmatic. He was trying to get to the truth."

More recently, Ross developed the recovery theorem, which allows the separation of probability distribution and risk aversion to forecast returns from state prices. His current research "focused on applying the recovery theorem to existing option pricing data, extending the recovery approach to fixed income markets, and using options to improve the performance of institutional portfolios," according to his biography on MIT Sloan's website.

"Steve Ross will be remembered as an intellectual giant," MIT Sloan Dean David Schmittlein wrote in a message to the MIT Sloan community. "What is known today about the science of finance and its application owes much to Steve's pioneering work, ranging from asset pricing to investment management to corporate finance. Steve did not believe in narrow specialization and intellectual boundaries. It is difficult to imagine the discipline of modern finance without Steve's contributions."

"Steve Ross was one of the giants of modern finance with a razor-sharp intellect and a heart of gold," said MIT Sloan Professor Andrew W. Lo. "The cold, hard logic of his mathematical theories stood in sharp contrast to the warmth of his personality. He was more humanist than financial economist, and was deeply connected in so many communities that would rightly claim Steve as their own. This is an enormous loss to MIT and the world."

—*By Zach Church*

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> **Steve Ross was one of the giants of modern finance with a razor-sharp intellect and a heart of gold.**"
>
> ANDREW W. LO

IN NOBEL PRIZE LECTURE, LESSONS FOR MANAGING EMPLOYEE INCENTIVES

MIT's newest Nobel Laureate, Bengt Holmström, discusses the challenges and opportunities offered by contract theory.

Pay for performance isn't easy to execute, and is more suited to stable industries and jobs where success can be easily quantified, Nobel Laureate Bengt Holmström said in Stockholm December 8, 2016, in a lecture as part of Nobel Week.

Holmström, who is a professor at both MIT Sloan and the MIT Department of Economics, shared the 2016 Svenges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel with Harvard University professor Oliver Hart. His lecture was titled "Pay for Performance and Beyond."

Holmström's research dates to the 1970s. He has conducted work on contract structure, employee contributions relative to their compensation, outside ownership of firms, and how to structure compensation to incentivize performance across all tasks, not just the most quantifiable.

UNEXPECTED ORIGINS FOR AN ECONOMIST

Holmström explained that his work has focused primarily on motivating workers, concentrating on contracts, though he never planned to be an economist at all. He started out as an applied mathematician in Finland, where he was hired by what he called a "progressive firm" to incorporate a corporate planning model.

"It was a wonderful way to learn how a big company works. I worked with a CFO, a tough guy who took a liking to me because I said what I thought," he said.

There, he worked on incenting models and researched how to incentivize people properly.

"I realized incentives were an interest of economists, too," he said.

SOLVING THE PRINCIPAL-AGENT PROBLEM

Holmström cautioned that "pay for performance" is complicated for a variety of reasons. He distilled this as the "principal-agent problem." Broadly speaking, principals are employers; agents are employees. They often have different motives. Contracts can be difficult because their preferences aren't aligned, and agent performance is imperfectly measured, he said. Contracted pay is then based on measured outcome. But his work has demonstrated that when an employee's performance pay focuses solely on short-term cash flow, for instance, it can backfire and risk the long-term health of a company.

UNDERSTANDING THE INFORMATIVENESS PRINCIPLE

Holmström discussed his informativeness principle, which weighs risks versus incentives. He explained that an ideal contract should link payment to all outcomes that can "potentially provide information about actions that have been taken."

To explain this, the Nobel committee uses the example of the manager whose actions influence her company's share price but not share prices of other firms. Should a manager's pay depend only on her firm's share

price? No: Because share prices reflect other factors in the economy outside the manager's control, only linking compensation to the firm's share price will reward the manager for good luck but punish her for bad luck. It's preferable to link the manager's pay to her firm's share price relative to those of similar firms, the committee explains, and not just on the share price she can work to control.

"The old accounting principle was that pay should only depend on variables an agent can control," Holmström said. Meanwhile, the harder it is to measure a manager's effort—and it often is, he said—the less pay should be based on performance.

"The level of effort is not the simplest case to study; it's about the most complicated. The behavior of the model is so erratic but seems simplistic," he said.

High-risk industries do better with fixed salaries; steadier jobs with more transparency can embrace additional performance measures, he said.

THE TROUBLE WITH MULTITASKING

He went on to discuss multitasking, which makes it harder for employers to monitor output. To dissuade an employee from concentrating on tasks where performance is easier to measure, weaker incentives are better. For instance, if teachers' salaries hinge mainly on quantifiable results like test scores, those teachers might spend too little time teaching more qualitative skills like creativity. A fixed salary, independent of performance measures, would lead to a more balanced effort.

"Some tasks are easy to measure; others are hard. And you have to consider that, even though you can easily observe one, quantity is easy to measure, but quality is harder. These are the dangers of multitasking," Holmström said.

He illustrated the pitfalls of over-incentivizing by pointing to "scandals" like Wells Fargo, where employees manufactured fake bank accounts to get bonuses, because they were paid for the number of accounts created. He also mentioned the Gulf oil spill, where excessive output incentives may have led to safety compromises.

"It's not that [employees] are evil, by the way. It's just that there's so much expected of them, and they feel like they have to manufacture somehow in order to hold on to their jobs," he said.

MULTITASKING LESSONS

"Don't incentivize competing tasks," Holmström said. To properly provide incentives, pay more for an important task or pay less for competing tasks. When a task is hard to measure, low or no incentives might be best.

Ultimately, he said, "employees want to be appreciated." Holmström discussed alternative incentives, like job design to match the needs of an employee, a non-pay-for-performance approach.

"There's a lot beyond pay for performance," he said.
—*By Kara Baskin*

KERRY ANN JAMES, SB '95, MBA '01

THE MIT SLOAN EXPERIENCE THAT HAD THE MOST IMPACT ON ME:

The trip to China I took during spring break of my first year probably had the most impact on me for a variety of reasons. It was the first time I had ever been to Asia, and it prompted my interest in travel more broadly to see the world and experience different cultures, which led me to a career where I traveled a lot. I learned so much about business and how it can be run very differently within different cultures. Lastly, I had the opportunity to get to know some of my classmates in a much deeper way than just seeing them in class and at C-Functions, creating some of the best friendships I have from Sloan.

HOW I STAY INVOLVED AND WHY:

I'm on the Dean's Alumni Committee working on volunteer programs this year, I was a reunion volunteer for our 15th Reunion last year, and I'm a class agent for the Class of 2001. I also love to connect with classmates when I go to different cities and countries, so you might find me with Sloanies in San Francisco, New York, London, or Hong Kong.

WHY MY DEAN'S CIRCLE GIFT MATTERS:

I believe in giving at the Dean's Circle level to help the school continue to be on the cutting edge of academics with great professors and leading research projects. By giving to the Annual Fund, I know my Dean's Circle gift can go to the areas where the school believes we need to build and grow. My Dean's Circle gift also matters because it helps bring up the level of scholarships the school can offer to great candidates to remain competitive.

Help ensure MIT Sloan's most vital legacy: more leaders like you. Membership in the Dean's Circle makes a greater impact by driving deeper inquiry, fueling more profound innovation, and creating groundbreaking ways for students, faculty, and alumni to live our mission of improving the world.

Learn more at mitsloan.mit.edu/alumni/deans-circle/

Dean's Circle
MIT SLOAN'S LEADERSHIP GIVING SOCIETY

SMARTER TOGETHER

Each year, the Office of External Relations holds a series of conferences for our alumni community. Bringing faculty leaders and alumni together across the country, each conference tackles some of the biggest issues facing the world today, envisioning solutions through collaboration, and proving we're smart enough to know that we're smarter together.

Visit mitsloan.mit.edu/alumni/events for a list of events near you.

FinTech and the Disruption of Finance: Perspectives from MIT Sloan School of Management

September 16, 2016

Over 300 alumni and friends gathered at TheTimesCenter in New York City where the audience heard presentations from faculty members Andrew W. Lo, Antoinette Schoar, Christan Catalini, and Roberto Rigobon, PhD '97. Simon Johnson presented his research into how central banks should respond to new digital currencies like bitcoin that have the potential to disrupt the flow of money all over the world. A special panel, "FinTech: Beyond the Startup," explored the disruptive nature of FinTech and was moderated by Robert Hedges, SM '84, and featured Ben Golub, SB '79, SM '82, PhD '84; Phillip Riese, SF '77; and Mona Vernon, SM '11.

For more information on the MIT Sloan Finance Group, visit: mitsloan.mit.edu/faculty-and-research/academic-groups/finance/

MIT Health Innovations: Technology, Analytics, and Systems
October 21, 2016

MIT Sloan faculty and industry leaders came together with over 200 attendees to discuss the challenges confronting the U.S. healthcare industry as it navigates a major transformation. The audience was treated to four panels and two keynote addresses, including "New Innovations in Healthcare," moderated by Christopher McLeod, SM '79, with Sofija Jovic, EMBA '14; Daniel Silberman, MBA '06; and Dina Katabi, SM '99, PhD '03. Professor Retsef Levi acknowledged that the health system is under significant pressure to change but, "what it needs to transform to is very different. The idea of health is going to be broader, more comprehensive. It's going to be team-based, patient-centric, and data-driven personalized care."
For more information on the MIT Sloan Initiative for Health Systems Innovation, visit: hsi.mit.edu/

Machine, Platform, Crowd: Harnessing the Digital Revolution
June 20, 2017

Over 200 attendees started the day with a keynote from Andrew McAfee, who encouraged the audience to rethink the integration of minds and machines, products and platforms, and the core verses the crowd. A series of fireside chats with alumni and industry leaders moderated by McAfee and Erik Brynjolfsson, PhD '91, explored each of the three elements in depth.
For more information on the Initiative for the Digital Economy, visit: ide.mit.edu

Celebrating a Half-Century of MIT Entrepreneurship
November 11–12, 2016

MIT Sloan celebrated more than 50 years of entrepreneurial research, education, and practice at MIT. The two-day conference featured panel discussions with faculty and alumni and demonstrations illustrating the breadth of entrepreneurship at MIT, with a special focus on the development of MIT's entrepreneurial program and its global reach. The program featured over 50 speakers over the two days including, Brad Feld, SB '87; Helen Grenier, SB '89, SM '90; Robert Langer, ScD '74; and Tom Leighton, PhD '81. Founder Ed Roberts, SB '57, SM '58, SM '60, PhD '62 was honored at a special reception at the conclusion of the conference featuring remarks from MIT President L. Rafael Reif, Dean David Schmittlein, and Martin Trust, SM '58, among others.
For more information on the Martin Trust Center for MIT Entrepreneurship, visit: entrepreneurship.mit.edu

MAKING THE GLOBAL FOOD SUPPLY CHAIN SAFER

By Jill Maxwell

Three years ago, Retsef Levi knocked on Tauhid Zaman's office door. Zaman, KDD Career Development Professor in Communications and Technology and assistant professor of operations management, studies social network data—how to catch ISIS operatives using Twitter, for example. Levi, J. Spencer Standish (1945) Professor of Operations Management, was working on a project for the U.S. Food & Drug Administration (FDA)—a risk model for stopping adulterated food imports at the border. Could Zaman join the team? "I had no idea how I'd fit in," Zaman says. But Levi and co-principal investigator Yasheng Huang, International Program Professor in Chinese Economy and Business, were right. Zaman was a piece of the puzzle—as were MIT Sloan's Y. Karen Zheng; the Center for Biomedical Innovation's Stacy Springs and Anthony Sinskey; and others from MIT's Electrical Engineering and Computer Science departments. Last fall, they delivered the predictive analytics tools they developed to the FDA.

Now, with millions of dollars in funding from the Walmart Foundation and the HNA Group, the interdisciplinary team is digging deeper into food supply chains in China, the world's third-largest food exporter with more than a billion of its own consumers. The researchers are collaborating with universities, industry partners, and government institutions there to build far greater transparency into food supply chains, and better understanding of risk drivers. Ultimately, they hope that their predictive models will prevent the purposeful adulteration of food.

The seed for this project was planted back in 2011, when the federal government passed the Food Safety Modernization Act. The United States imports about 40 million individual

THE UNITED STATES IMPORTS ABOUT 40 MILLION INDIVIDUAL SHIPMENTS OF FOOD EVERY YEAR, AND MANY OF THOSE SHIPMENTS ARE COMING FROM COUNTRIES THAT LACK THE BASIC QUALITY CONTROLS IN PLACE IN THE UNITED STATES.

Retsef Levi, J. Spencer Standish (1945) Professor of Operations Management

shipments of food every year, and many of those shipments are coming from countries that lack the basic quality controls in place in the United States. It would be simply impossible to check every box—and yet, farmers and manufacturers have adulterated food for

a variety of reasons. "In response to avian flu, for example, there was an increase in extensive use of antibiotics, antivirals, and herbal medicines" in poultry farming throughout Asia, Levi says. In 2008, the Chinese government started requiring a level of protein in milk and at the same time capped its price, which prompted some in the dairy trade to add melamine—a poison—to fake their way through the tests. And during outbreaks of early mortality syndrome in 2009 and 2013, farmers increased their use of

antibiotics and other additives in shrimp. "All of these cases indicate that you might be able to understand what kind of socioeconomic and environmental drivers could increase the level of risk" that a particular food might have been tampered with, Levi says. So when the FDA needed some new tools, they approached MIT for help. The Abdul Latif Jameel World Water and Food Security Lab (J-WAFS), MIT's food and water security lab, also provided a grant of funding.

The researchers sat together with their students and brainstormed. "We had to approach it like detectives," Zaman says. "What would make a company look fishy?" One month in, the researchers found a website with copies of bills of lading—the start-to-finish shipping records for every container that moves. They paired that data with FDA inspection records and started to look for patterns.

Sloan School Career Development Professor Y. Karen Zheng studies human behavior in supply chains. She targeted one thousand Chinese manufacturers of honey, poultry, pork, seafood, and eggs. She mapped their supply chains back to individual farmers, recording the volume each farmer provided, the distance from the farm to the factory, and more. To supplement the FDA sampling data, Zheng's students gathered data online from other countries that import from China. "About halfway through the project, we were actually quite lucky," Zheng says. "The Chinese government frequently samples products from retail shelves. In 2015, they started to publish those sampling results online."

Stacy Springs, director of the Biomanufacturing Research Program at MIT's Center for Biomedical Innovation (CBI), focused on case studies of companies that had been caught adulterating food—both in the past and in some ongoing cases that aren't yet fully understood. She zeroed in on which chemical or biological contaminants were popping up. "We tried to approach it very systematically by asking ourselves, 'What are the potential adulterants?,' and then characterizing the possibility that those have actually infiltrated the food supply," she says.

Everyone had to deal with data that was dirty or slow in coming. The same company's name could be spelled three different ways, for example. And government bureaucracies don't

disseminate data via firehose. But the team plugged away. Once or twice a week, they came together in a conference room at MIT Sloan or CBI to touch base, share data, and plan their next steps.

Here's what they discovered. "The coolest thing we found is a way to predict if a company is going to be adulterating food. The company's product network gives it away," Zaman says. He'd theorized that companies with a more diverse mix of products would fail inspections more often. If Company A imports shrimp, fish, and squid, it's usually okay, Zaman says: "It's all seafood; they know their suppliers." But if Company B imports shrimp and paint, "that's kind of weird," Zaman says. "To them, they're just looking for another cheap product." Zaman graphed the modularity of each company and confirmed that the diversity of a company's product mix does, in fact,

rank of officials engaged in misconduct. Manufacturers in cities where the mayor had engaged in misconduct had more problems," Zheng says. Also, she says, "cities in which a large fraction of the companies engage in tax evasion are significantly correlated with risk. Food companies in those regions also turn out to have more problems."

A recent gift from the Syngenta Foundation will fund Zheng's newest research, which will focus on discovering when and how consumers value traceability of food products and how various sourcing strategies impact the resulting safety and quality of agricultural products.

Other risk factors the team identified include the number of farmers supplying a manufacturer, the number of shipments a company sends overseas, and whether an exporter ships through a middleman

OTHER RISK FACTORS THE TEAM IDENTIFIED INCLUDE THE NUMBER OF FARMERS SUPPLYING A MANUFACTURER, THE NUMBER OF SHIPMENTS A COMPANY SENDS OVERSEAS, AND WHETHER AN EXPORTER SHIPS THROUGH A MIDDLEMAN COUNTRY ON THE WAY TO THE UNITED STATES.

correlate with failed inspections. "I was surprised by how well our predictive model did—just that single feature," he says.

Zheng and Huang were able to correlate regional regulatory oversight and even tax evasion with food shenanigans. They hypothesized that of 320 cities in China, those with weak governance were more likely to be the origin of an adulterated shipment. "One measure that seemed to stand out was the

country on the way to the United States.

Meanwhile, the Walmart Foundation was already working on the food safety situation in China. Impressed with MIT's risk modeling, the foundation provided funding to take the project to the next level, including the development of new tests. Current food-testing methods require testers to know which contaminant they're looking for. Biology professor Anthony Sinskey and new team member Michael Strano of Chemical

"Bringing this team together allows us to simultaneously view where the vulnerabilities in the supply chains are and then develop the technology to make them more secure."

YASHENG HUANG
International Program Professor in Chinese Economy and Business and Professor of Global Economics and Management

Engineering are developing sensor platforms capable of measuring not just one but hundreds of potential adulterants simultaneously, in real time, on a hand-held device.

And the team is working with their Chinese counterparts as part of a food safety collaboration center. "We'll be able to track stock prices and social media feeds and see hot spots lighting up on maps," says Zaman. "It will be proactive. It will allow intervention."

The collaboration is a prime example of a cross-campus project that might only happen at MIT. "It's a rare opportunity to bring so much expertise together to tackle a problem like this," says Springs. "Bringing this team together allows us to simultaneously view where the vulnerabilities in the supply chains are and then develop the technology to make them more secure."

HNA Group, inspired by this collaboration, and the work in progress, is now helping MIT scale its potential impact. Huang, who presented the team's findings to MIT alumni in Hong Kong at the Campaign for a Better World Tour last December, agrees. "It will be a game changer if we succeed," he says. But the work is only beginning. "The problem is not going away," Huang says. "We need to raise the resources that will give permanence to what we're doing." ● ● ●

BATTLING CYBERCRIME

MIT TACKLES A GLOBAL CHALLENGE

By Alix Stuart

Cybersecurity is a topic that regularly frustrates executives and government officials. They spend inordinate time and worry trying to protect their data, yet on balance, it's a losing battle. Nearly two-thirds of Americans say they've had digitized personal information stolen, according to a recent survey by Pew Research Center, and few have confidence in companies or the federal government to protect them.

Sophisticated phishing schemes, ransomware, state-sponsored hacking, and the like certainly contribute to this maddening struggle. But at the heart of the problem is a simple fact: "People tend to think cybersecurity is solely a technology problem," says MIT Sloan's Stuart Madnick, the John Norris Maguire (1960) Professor of Information Technology and academic director of MIT Sloan's Interdisciplinary Consortium for Improving Critical Infrastructure Cybersecurity, also known as (IC)³.

Instead, "cybersecurity issues are multi-faceted, much like a multi-headed hydra," says Madnick, "so they need to be addressed in a multi-disciplinary manner—which is one of MIT's great strengths." Consider a ransomware attack that effectively locks up an organization's data and systems. On the surface, this problem—which many hospitals have faced in the past year—is a technical one: Can the data be unlocked, and how fast? But embedded within it is a host of management problems, as well, including decisions about whether to pay the ransom, how the organization should operate if its data remains locked, and whether new policies are required to respond to similar issues in the future.

To achieve a more holistic approach on cybersecurity, Madnick and other MIT Sloan faculty are increasingly collaborating internally and across the MIT campus, with the goal of getting ahead of the real-world problems that keep executives and political leaders up at night. Research topics range from the governance of the internet to global trade policies for cyber-risky internet-enabled devices to new approaches for calculating the costs and benefits of cybersecurity investments.

"Cybersecurity has technical, trade, and policy implications, along with the managerial ones. If you can't bring together all those forces, you can only launch a partial attack," says Madnick.

And MIT Sloan is exactly the right place to combine such forces. With a rich history of collaboration across the campus, "the ability to bring world-class technology and engineering resources to address managerial problems is unparalleled," says
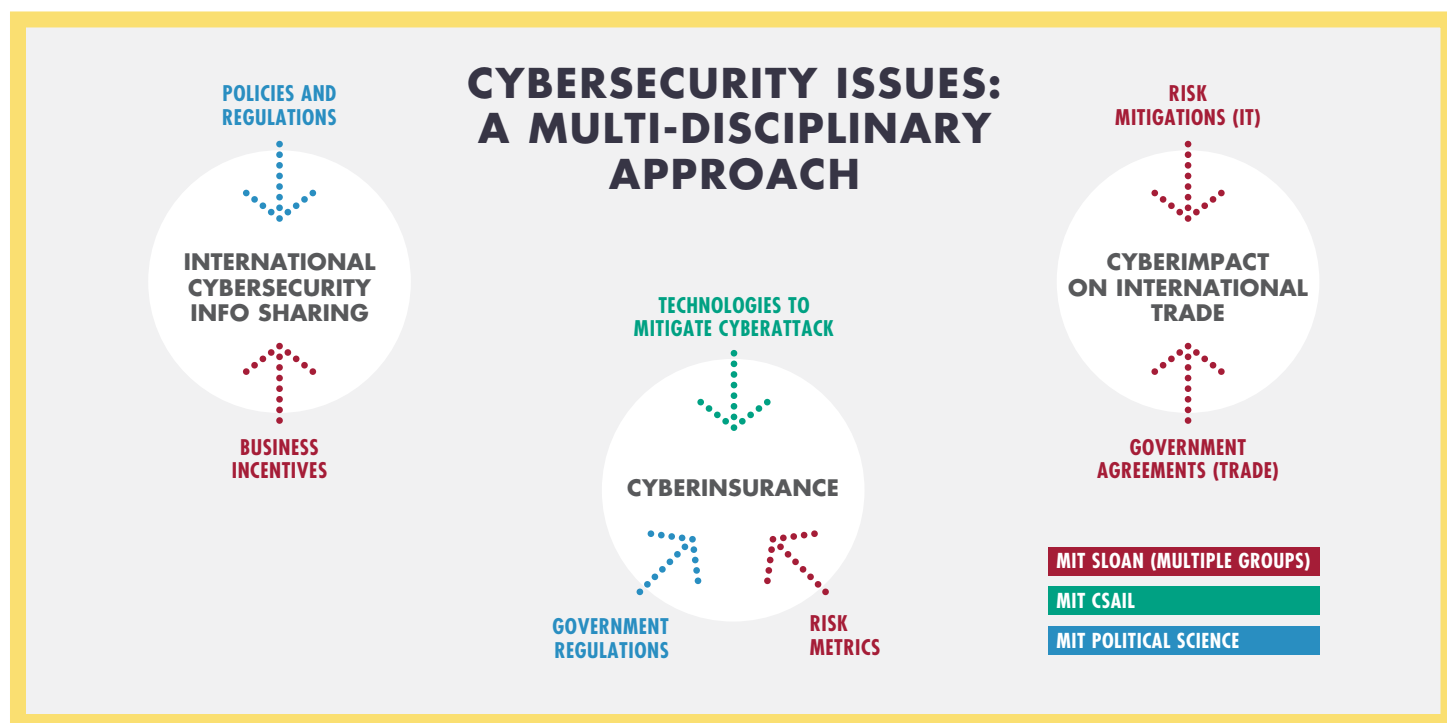
Madnick. Plus, cybersecurity is increasingly rising to the level of being the type of "really hard problem" that MIT exists to overcome. "This sits right in the center of our mission to make the world a better and safer place."
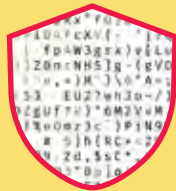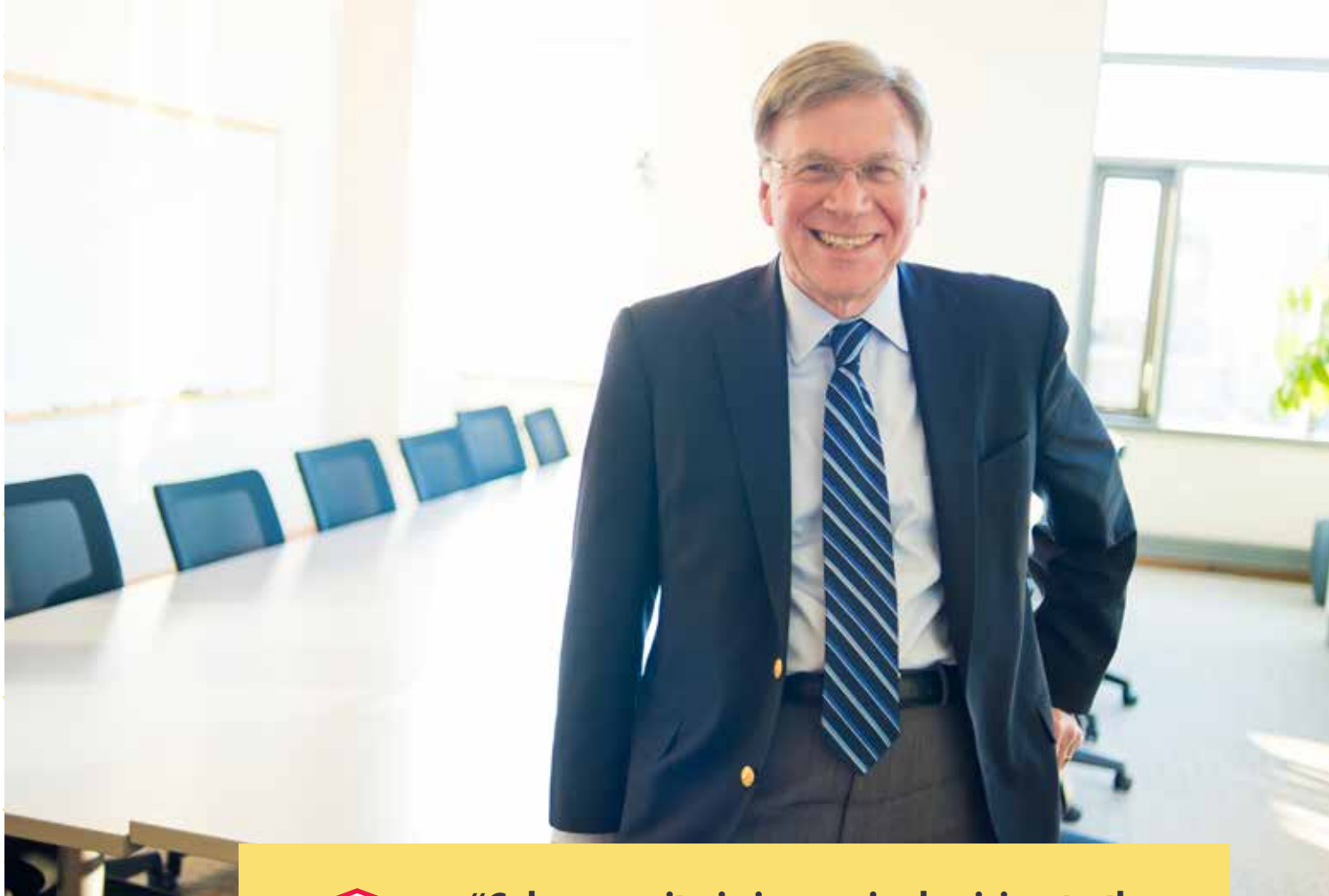
WHO'S THE BOSS?

A big question anchoring a major strand of MIT Sloan research collaboration is: Who exactly is in charge of cyberspace? Who is policing its borders, and who is to blame when things go wrong? While each country may have its own policies and governance for the internet, there is little coordination among them. And many elements of cyberspace transcend existing country borders: The undersea cables that carry nearly all internet traffic crisscross the globe, for example.

"Existing law is attached to countries, but the internet is not just about countries," notes Nazli Choucri, an MIT professor of political science, who is currently working with Madnick to examine what new structures or rules the boundless world of cyberspace might require. In her view, cyberspace will require a new set of laws, as well as new transnational institutions to govern it. And that has major implications for company decision making, since "country-level issues and consequences are inexorably woven with company-level issues and consequences," says Madnick.

So far, though, countries don't typically even share information about when or how often they've been hacked, much less discuss how to band together against such attacks. "Often, we don't agree

CYBERSECURITY ISSUES: A MULTI-DISCIPLINARY APPROACH

POLICIES AND REGULATIONS

INTERNATIONAL CYBERSECURITY INFO SHARING

BUSINESS INCENTIVES

TECHNOLOGIES TO MITIGATE CYBERATTACK

CYBERINSURANCE

GOVERNMENT REGULATIONS

RISK METRICS

RISK MITIGATIONS (IT)

CYBERIMPACT ON INTERNATIONAL TRADE

GOVERNMENT AGREEMENTS (TRADE)

MIT SLOAN (MULTIPLE GROUPS)
**MIT CSAIL**
MIT POLITICAL SCIENCE

across countries on how to define cybersecurity or incidences of cyberattacks," Choucri says. "On the obvious issues, governments across the world do not willingly share information, and neither do international institutions that are presumably above the fray."

That's the bad news. But Choucri's work with Madnick seeks to catalogue existing practices and move forward with a framework and standards that would make it easier for sharing to occur. Improving cybersecurity information sharing will actually improve cybersecurity, their research proposal notes. "We are seriously lagging in basic interaction," says Choucri. "As a result, we may be creating serious opportunity costs—for all."

In hopes of broadening the perspectives of the next generation of leaders, Choucri and Madnick co-taught a cybersecurity course last semester that featured a variety of guest speakers, such as researchers from the MIT Center for International Studies within the Political Science department and the Internet Policy Research Initiative (IPRI) and Cybersecurity@CSAIL; an initiative within the Computer Science and Artificial Intelligence Lab (see sidebar on page 24). This course was cross-listed in both MIT Sloan and the Political Science department. "We're teaching cybersecurity from both a geopolitical point of view and from a business point of view, then including fundamentals like the architecture of the current internet," says Choucri. "Those three sides are all closely interwoven; you really can't untangle them."

Meanwhile, IPRI is a cross-MIT research initiative that is examining related themes. "Our goal at IPRI is to develop technically grounded internet public policy options for governments around the world," says IPRI founding director Daniel J. Weitzner, former U.S. Deputy Chief Technology Officer for Internet Policy in the White House. With faculty leadership from MIT Sloan
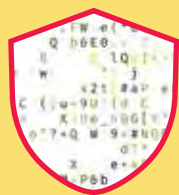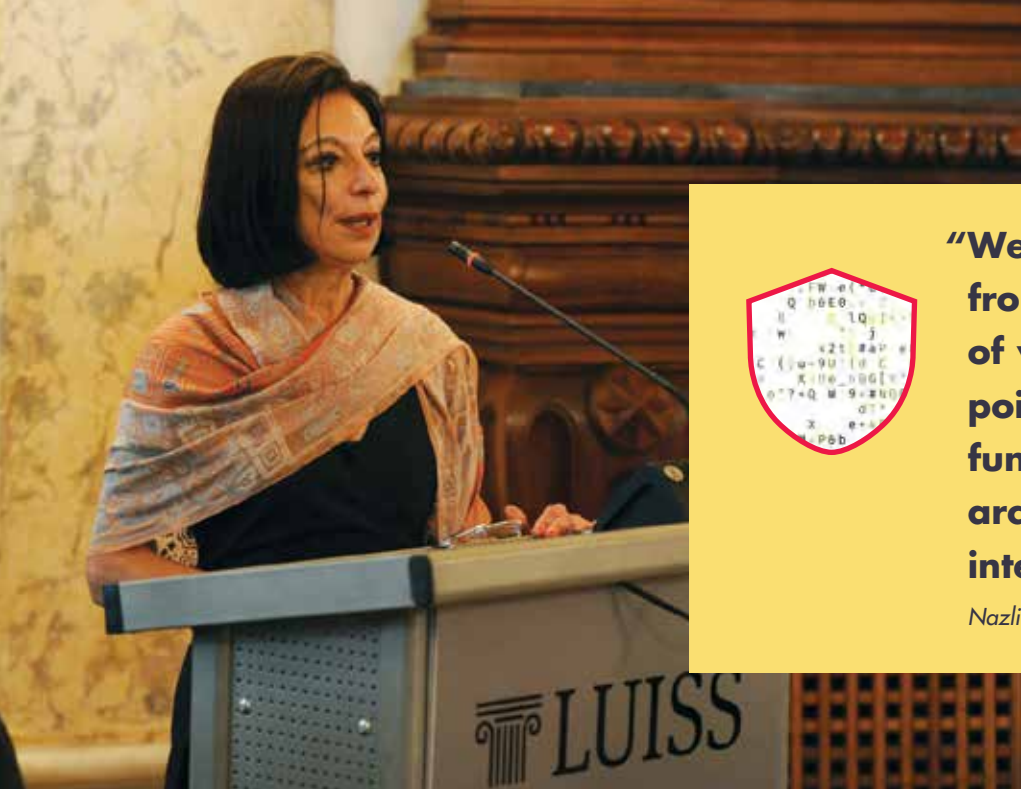
> "We're teaching cybersecurity from both a geopolitical point of view and from a business point of view, then including fundamentals like the architecture of the current internet."
>
> *Nazli Choucri, MIT Professor of Political Science*

as well as departments such as Political Science, EECS, Sociology, and Anthropology, research in IPRI spans policy aspects of encryption, protecting critical infrastructure, privacy, network architecture, and machine understanding. Related materials, in particular case studies that explored the questions arising from the conflict between Apple and the FBI over access, were used in MIT Sloan's module of ethics of cybersecurity.

EYES EVERYWHERE

Against the backdrop of such a big-picture, systemic investigation into the internet, an emerging project within MIT Sloan is looking at what it means to have the power of the internet embedded in small devices throughout our lives.

The Internet of Things—the catchphrase for the rapidly growing class of internet-enabled devices such as smart TVs and self-driving cars—is largely known for its convenience factor. According to leading economist Simon Johnson, PhD '89, however, it is a threat to global trade and national security. Together with Madnick, Johnson—the Ronald A. Kurtz (1954) Professor of Entrepreneurship and professor of global economics and management at MIT Sloan—is investigating how governments are and should handle imports of items that could ultimately be a conduit for harming their citizens.

While it may sound far-fetched, some governments are already dealing with such concerns. Since 2012, for example, the U.S. Congress has urged U.S. telecommunications companies not to purchase network equipment from two Chinese companies, Huawei and XTE, for fear that the hardware could

funnel intelligence back to China. On the flip side, this year Germany banned an interactive toy made by U.S.-based Genesis Toys, My Friend Cayla, on the grounds that the doll's internal camera could be used to spy on its citizens.

"These are harbingers," said Johnson, of a scenario in which countries, by attempting to block the potential for international spying via internet-enabled devices, could force global trade to grind to a halt. That's because as the scope of products with internet connections extend to such common items as toothbrushes, such restrictions could effectively cover the majority of products—except perhaps bricks, Madnick remarks.

While the research is still in its formative stages, one of the project's aims is to create a framework that policymakers could use in constructing treaties with foreign governments. For governments, "the question is who trusts us and whom do we trust, in terms of what may be embedded in electronics—or really anything that has any kind of electrical element," says Johnson. The follow-on question is "Can you converge on some type of standards?" so that trade can continue flowing despite the malicious potential of some items.

Johnson and Madnick are hoping that large multinational companies will play a prominent role in the research, and welcome feedback from them. A major open question is whether standards should cover companies as entities or simply individual product lines. "If you trust Apple, does that mean anything they produce is fine?" Johnson asks. Companies will also have to decide how to respond to the fact that governments appear increasingly

able to work around their security measures in order to, say, unlock phones of those involved in crimes, or listen in on cellphone conversations for signs of suspicious behavior.

NEW MATH, TIMELESS PROBLEMS

Yet another dimension of narrow thinking around cybersecurity is the impulse to underinvest in defensive measures, since it's difficult to measure how effective any given level of spending is. "There are about 100 well-known ways you can improve your cybersecurity, and if everyone did all of them, we'd probably improve quite a bit," says Jerrold Grochow, an MIT Sloan PhD who was formerly MIT's vice president of information systems and technology, and is now a research affiliate with MIT Sloan and the (IC)[3] initiative. "The problem is that these measures cost money, and it's not a one-time thing; you have to constantly maintain them."

Grochow is now working on an economic model that would make such management decisions more straightforward. "We're unlikely to get to something as simple as a return-on-investment calculation that people can specify with absolute certainty, but I think we can get to some calculations that say, "If you think a cyber event is no more or less likely to happen every N years, then you should be spending X amount of money because the payoff is Y," he says.
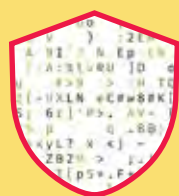
> ## "The question is who trusts us and whom do we trust, in terms of what may be embedded in electronics—or really anything that has any kind of electrical element."
>
> *Simon Johnson, PhD '89, Ronald A. Kurtz (1954) Professor of Entrepreneurship and Professor of Global Economics and Management*

(From left) S.P. Kothari, Howard Shrobe, President L. Rafael Reif, Daniela Rus, Maria Zuber, Daniel Weitzner, Stuart Madnick, and Director of MIT Lincoln Laboratory Eric Evans

Cybersecurity@MIT: A Three-Legged Stool

Anticipating the constantly increasing threats posed by cybersecurity, in March 2015, MIT officially announced the Cybersecurity@MIT Initiative. It consists of three interrelated multidisciplinary cybersecurity research efforts: Cybersecurity@CSAIL, focused on improved hardware and software; the Internet Policy Research Initiative (IPRI), focused on policy; and the Interdisciplinary Consortium for Improving Critical Infrastructure Cybersecurity, (IC)³, focused on the managerial, organizational, and strategic aspects of cybersecurity.

At the kickoff event, MIT President L. Rafael Reif emphasized both the new initiatives' partnerships with industry and the interdependence of the research programs. "New technologies will require new policies and incentives," he said. "Emerging policies must adapt to future technologies. And none of that matters if they cannot make the present a safe place to do business."

The IPRI works directly with policymakers and technologists to help solve problems. Led by former U.S. Deputy Chief Technology Officer for Internet Policy in the White House Daniel Weitzner, as well as faculty researchers from engineering, social science, and management labs at MIT, the center recently published a set of presidential-level policy recommendations based on a two-year analysis of critical energy, finance, and communications systems in the United States. A past report on encryption policy, "Keys Under Doormats," was a key input to the FBI/Apple encryption debate, and led to the report's authors testifying before the U.S. Congress four times. Many of the IPRI projects have co-principal investigators from

two or even three different departments including MIT Sloan, reflecting the interdisciplinary aspect of cybersecurity policy.

The Computer Science and Artificial Intelligence Laboratory (CSAIL), the largest lab on campus, was created by the merger of two predecessor labs that date back to the 1950s—one was the Laboratory for Computer Science (LCS), where the first user IDs and passwords were introduced, and where Madnick received his PhD. CSAIL has long been at the forefront of internet and security issues, from developing large parts of the internet architecture to creating data encryption systems. It is home to the World Wide Web Consortium (W3C), directed by Tim Berners-Lee, inventor of the web.

While it often takes years to move from research to commercially available products, CSAIL has already helped some promising startups in the cybersecurity field get off the ground. In 2016, for example, the startup PatternEx launched its first service offerings, based largely on CSAIL research that combined human input with artificial intelligence to predict cyberattacks

about three times more accurately than previously existing products. PatternEx co-founder Kalyan Veeramachaneni launched it as a research scientist at CSAIL with Una-May O'Reilly's research group AnyScale Learning For All (ALFA); the company's chief data scientist, Ignacio Arnaldo, is a former ALFA and CSAIL post-doc.

Besides the differences in research focus, each of the three programs has its own unique operational model. Cybersecurity@CSAIL is currently sponsored by seven leading firms from distinct industries, including aerospace, energy, and financial services. "The research is really informed by problems that industry is facing—and then it makes its way back out of the laboratory to address the problems," says Lori Glover, managing director, CSAIL Alliances, and executive director, Cybersecurity@CSAIL.

(IC)³ includes 23 member firms across sectors, with multiple representatives from each industry. In general, companies choose a specific "stool" to affiliate with, but find a number of opportunities to cross-pollinate as CSAIL sponsors may attend (IC)³ meetings, and (IC)³ partners may attend CSAIL meetings. This overlapping cooperation also occurs in many other ways. The two centers have jointly organized events, such as a panel on cyberinsurance and a detailed presentation of the Ukrainian power grid attack.

Part of that effort involves collecting data from companies to compare spending trends with breaches at different organizations. At the same time, Grochow and others, including Madnick and principal research scientist Michael Siegel, are proposing to use MIT as a laboratory to test the effectiveness of one generally accepted security practice: two-factor authentication, in which users must present a combination of evidence such as a password and a code texted to their smartphone to gain access. Two-factor authentication was recently mandated on campus, and Grochow is hoping to collect data that would one day allow a security professional to predict the percentage drop in data breaches as a result of implementing it. Overall, "the point is to quantify how effective some of these common practices are and balance that against the cost," he says.

THE PRICE OF HUMAN NATURE

Incorporated in these calculations, however, is a growing effort to understand how the so-called "human factor" can undercut pricey defense systems. In recent years, it's become clear that no matter how good firewalls and virus protection software may be, people often make mistakes that allow cyberattackers easy entrance. For example, phishing schemes—in which attackers send emails posing as someone well known to the recipient—have been highly successful in convincing people to give up passwords, bank account information, and other sensitive data with almost no coercion. One recent example—the May 2017 "WannaCry" attack—impacted over 200,000 computers in thousands of corporations in over 100 countries within hours.

THE "WANNACRY" ATTACK IMPACTED OVER **200,000** COMPUTERS.

In other situations, human efforts to cope with the complexity of security measures makes them more vulnerable to attack. Catherine Tucker, Sloan Distinguished Professor of Management and professor of marketing, found that the number of publicized data breaches actually increased after organizations implemented encryption technology, based on a study of hospitals published in 2011. Other studies have shown that mandating frequent password changes can be counterproductive. The reason? Faced with hard-to-remember passwords, employees often resort to shortcuts that make it easier for thieves to enter, such as writing passwords on sticky notes, Tucker and co-author Amalia Miller of the University of Virginia hypothesized. Pew research backs this up: 49 percent of respondents admitted to writing down passwords to help remember them.

The upside of human error issues is that they don't always require high-priced tools to fix. "There are a lot of small behavioral things organizations can do that help a lot," says Grochow. For his part, he asked all of his employees to add a line to their email signature saying "No one in our department will ever ask you for your password" when he headed information systems and technology for MIT. "That meant that hundreds of people saw that message multiple times every day—an easy and effective way to get the point across and affect behavior," he adds.

CYBERINSURANCE

MIT has been asked by the Geneva Association, the major insurance think tank, to explore the opportunities and challenges of cyberinsurance. Madnick is working with the Boston Consulting Group, and researchers, such as Howard Shrobe in CSAIL, on technologies to reduce risks. Choucri is studying government regulations and how they may even be in conflict for multi-national operations, and other colleagues at MIT Sloan are examining better ways to measure risk, especially for rare potential catastrophes.

A TIPPING POINT

Will cybersecurity still be an issue that keeps executives up at night 10 years from now? Most likely, yes. "The good guys are getting better, but the bad guys are getting badder faster," says Madnick. But armed with better data, smarter networks, and a more holistic view of how to protect themselves, executives may be able to get back to sleep faster. ● ● ●

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2011	YuXin Xia, MBA	December 22, 2016

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