Institute for Data, Systems, and Society

The new MIT Institute for Data, Systems, and Society (IDSS) launched on July 1, 2015. Spanning all five MIT schools, IDSS is committed to addressing complex societal challenges by advancing education and research at the intersection of statistics, data science, information and decision systems, and social sciences. IDSS aims to develop new analytical methods to address complex, significant societal challenges in a diverse set of areas such as finance, energy systems, urbanization, social networks, and health.

Technology advances in areas such as smart sensors, big data, communications, computing, and social networking are rapidly scaling the size and complexity of interconnected systems and networks—and at the same time are generating large quantities of data that can lead to new insights and understanding. Research at IDSS seeks to understand and analyze data from across these systems and gain clear, actionable insights.

Faculty and Leadership

The director of IDSS is Munther Dahleh, the William A. Coolidge Professor in the Department of Electrical Engineering and Computer Science (EECS). Associate directors are EECS professor Asuman Ozdaglar, who is also director of the Laboratory for Information and Decision Systems (LIDS), and Ali Jadbabaie, a visiting professor from the University of Pennsylvania who is also interim director of the Sociotechnical Systems Research Center. John Tsitsiklis, the Clarence J. Lebel Professor of Electrical Engineering, is the IDSS graduate officer. EECS professor Devavrat Shah has been named director of the MIT Statistics and Data Science Center. More information about the institute's faculty and administrative leadership is available at the IDSS website.

The approximately 80 IDSS faculty members include core, affiliate, and visiting faculty members from a variety of areas throughout the Institute. IDSS recently welcomed the following new MIT faculty:

> Guy Bresler, assistant professor of electrical engineering and computer science
>
> Caroline Uhler, assistant professor of electrical engineering and computer science
>
> Ali Jadbabaie, JR East Professor of Engineering
>
> Alberto Abadie, professor of economics

Faculty Awards, Recognition, and Promotions

Faculty highlights for 2015–2016 include:

- Philippe Rigollet, associate professor of mathematics, was granted tenure.
- Munther Dahleh received a 2017 Fellow Award from the International Federation of Automatic Control.
- Tamara Broderick received two awards at the 2016 World Meeting of the International Society for Bayesian Analysis in Sardinia.

- Victor Chernozhukov, professor of economics and core IDSS faculty member, was elected to the American Academy of Arts and Sciences.

- John Tsitsiklis received the 2016 Association for Computing Machinery SIGMETRICS Achievement Award.

- Paul Grogan and Olivier de Weck's "Collaborative Design in the Sustainable Infrastructure Planning Game" won the best paper award at the Spring Simulation Multi-Conference Annual Simulation Symposium.

- The International Association for the Advancement of Space Safety selected Professor Nancy Leveson as the recipient of its 2016 Vladimir Syromyatnikov Safety-by-Design Award.

- Stefanie Jegelka received a Google Research Award in the area of machine learning.

- Devavrat Shah was promoted to full professor.

- Jonathan How, the Richard C. Maclaurin Professor of Aeronautics, was elected a fellow of the American Institute of Aeronautics and Astronautics.

- Daron Acemoglu, Munther Dahleh, and Emilio Frazzoli (together with collaborators Giacomo Como from Lund University and Ketan Savla from the University of Southern California) won the IEEE (Institute of Electrical and Electronics Engineers) Control Systems Society's 2015 George S. Axelby Outstanding Paper Award for "Robust Distributed Routing in Dynamical Networks–Part II: Strong Resilience, Equilibrium Selection and Cascaded Failures." The award recognizes the best paper published in the past two years in IEEE Transactions on Automatic Control.

- The 2015 Doherty Professorship in Ocean Utilization was presented to Professor Caroline Uhler.

- Noelle Selin was named one of the first Leshner Leadership Institute Public Engagement Fellows by the **American Association for the Advancement of Science**.

- G. David Forney Jr., an adjunct professor in EECS and LIDS, received the 2016 IEEE Medal of Honor.

- Asuman Ozdaglar was appointed to the Joseph F. and Nancy P. Keithley Professorship in Electrical Engineering.

- Guy Bresler was named the Bonnie and Marty (1964) Tenenbaum Career Development Professor.

- Stefanie Jegelka received a prestigious prize from the German Pattern Recognition Society for her research efforts in machine learning.

Major Events

During the 2015–2016 academic year, IDSS presented the following ongoing events:

IDSS Distinguished Seminar Series

IDSS Special Seminar Series

Stochastics and Statistics Seminar Series

LIDS Seminar Series

In addition, on April 8, IDSS presented the Workshop on Data, Analytics, and Risk in Finance. This workshop focused on opportunities related to big data and predictive analytics in finance and economics, including new approaches to modeling, measuring, and understanding risk. Invited participants brought perspectives from across disciplines such as finance, economics, statistics and data science, and social sciences. The event explored innovative ideas at the intersection of these fields.

Academic Programs

IDSS students will address societal challenges by combining the fundamentals of statistics, data science, and information and decision systems with a rigorous study of social sciences. IDSS comprises some new academic programs, including the Doctoral Program in Social and Engineering Systems and new and upcoming efforts in data science and statistics, as well as the long-running Technology and Policy Program.

Doctoral Program in Social and Engineering Systems

The Doctoral Program in Social and Engineering Systems (SES) was launched during the past academic year. This unique research program focuses on addressing concrete and societally significant problems by combining methods from engineering and the social sciences.

Curriculum

The first part of an SES student's program consists of advanced, rigorous, and challenging classes and includes three core classes covering fundamentals; five classes in information, systems, and decision sciences; four classes in the social sciences; and two classes focusing on an application domain. After several semesters of coursework, students take a qualifying exam with both a written and an oral portion. Successful completion of the oral exam, generally in a student's fourth to sixth semester, marks the transition in academic activity from classes to research.

Research

Immersion in research is the centerpiece of the SES program. Student research in SES is characterized by the following traits:

1. It is driven by problems of societal interest in areas such as energy, finance, health care, social networks, and urban science, as well as in policy-related topics.

2. It is application-domain driven, with a focus on solving concrete problems while developing methodologies as necessary, as opposed to the development of generic, context-independent methodologies.

3. It heavily relies on quantitative methods. The program is focused on problems that can be addressed through mathematical modeling and data analysis.

4. It relies on real-world data. Research is expected to analyze data from the application domain of interest and draw upon the training provided in statistics and other areas through program coursework.

5. It engages societal aspects of problems, incorporating theories and tools from the social sciences.

Program Milestones

October 21, 2015: the MIT Faculty voted to create a new doctoral degree in social and engineering systems.

December 27, 2015: applications were due for the first round of admissions to SES.

February 2016: admissions offers for fall 2016 were sent to the first SES class.

April 2016: SES's first class of 10 students accepted offers of admission.

Admissions

The admissions cycle for September 2016 was the program's first. The planned start of the admissions cycle was delayed by more than a month as SES cleared its final round of MIT faculty governance approvals in mid-October 2015. To allow applicants sufficient time, the application deadline was extended by two weeks. Nevertheless, advertising, networking, and the assistance of EECS led to 241 targeted applications for the new program. This is nearly double (197%) the largest-ever annual application pool of SES's predecessor program. In addition, nearly 750 EECS applicants indicated their interest in being considered for the SES program.

SES Applications for September 2016

Targeted and indirect applications	~980
Targeted applications	241
Admitted students	17
Students starting in September 2016	10
Deferrals	2
Yield (%)	67–71

Student Support

The 10 students starting in September 2016 will be supported by seven research assistantships (two arising from IDSS seed funds) and three fellowships in their first year in the program.

Employment Opportunities

The overall profile and skill set to be acquired by the program participants is one whose value has been rising in recent years. There is growing interest in the systems aspects of energy systems, finance, health care, social networks, and urban science, as well as industry, the public sector, and academia. It is expected that students will have access to a broad spectrum of employment opportunities.

Technology and Policy Program

The Technology and Policy Program (TPP) is an interdisciplinary graduate program, formed in 1975, that educates students focusing on issues at the interface of technology, society, and the sociotechnical aspects of complex systems. TPP is dedicated to educating engineers and scientists with a desire to lead in the development and implementation of responsible technology strategies and policies to benefit humankind. Three principles emerging from this mission frame our educational objectives:

- Dual professional excellence in engineering or science and policy analysis and development
- Knowledge and flexibility to manage conflicting interests and values at all stages of the policy process
- Effective leadership and communication skills in the technology policy process

Students

TPP offers a two-year master of science program and encourages its students to pursue doctoral research in the areas of technology, management, and policy. TPP's applicant cohort is diverse, with applications coming from students in undergraduate programs around the world, many of whom have additional practical work experience. Additionally, several students already taking part in other MIT graduate programs enroll in TPP each year, joining the roughly one third of TPP students concurrently pursuing a second master's or doctoral degree in another department. The annual program intake averages 40 students, more than 40% of whom are women and approximately 40% of whom are international students.

Graduation and Employment

In AY2016, 44 students graduated with an SM in technology and policy, 11 of whom earned a second SM. Seventeen of these graduating students are entering PhD programs, largely at MIT. Other graduates take jobs in industry, government service, start-ups, or consulting. Of the roughly 1,200 graduates of TPP over its 40-year history, about 40% currently work in industry, 20% in consulting, 15% in academia, 12% in government, and the rest in other industries (e.g., law, nonprofit).

Research

Many TPP students are affiliated with the MIT Energy Initiative, where they study the challenges of energy choices, sustainability policy, and environmental responsibility. TPP students also conduct research for many other labs and centers across campus, including the Tata Center for Technology and Design, the Joint Program on the Science

and Policy of Global Change, the Center for Energy and Environmental Policy Research, the Center for Complex Engineering Systems, the Computer Science and Artificial Intelligence Laboratory, the Sloan Sustainability Initiative, and a number of research initiatives connected with IDSS such as the Lean Advancement Initiative and the Sociotechnical Systems Research Center.

TPP faculty are engaged with the MIT Portugal Program (MPP) in bioengineering systems, sustainable energy and transportation, and design-inspired products. Many TPP students are pursuing collaborative international research projects in engineering systems as part of MPP. TPP students are also working with Draper Laboratory, MIT, and Singapore University of Technology and Design (SUTD) faculty in the development of new curricula for SUTD and, in particular, the International Design Centre. On campus, TPP faculty are engaged in research, along with TPP students, in MIT initiatives such as the Environmental Solutions Initiative and the Abdul Latif Jameel World Water and Food Security Lab.

Fellowships

TPP students received a number of MIT fellowships, including Legatum, MIT Energy Initiative, Tata, Lincoln Laboratory, Keil, Leading Technology and Policy, and MIT-SUTD fellowships as well as the Office of the Dean for Graduate Education Diversity Fellowship. External fellowships awarded to TPP students included fellowships from the National Science Foundation and fellowships from Japan and Chile.

Policy Internship Program

Ten TPP students representing five countries traveled to Washington, DC, in March 2016. This annual trip gives students an opportunity to build professional networks with others working at the intersection of science, technology, and policy. TPP alumni arranged and hosted presentations at the National Aeronautics and Space Administration (NASA), Third Way, the Science and Technology Policy Institute, the Federal Emergency Management Agency, the Office of Science Technology and Policy at the White House, the US Department of Energy, the US Department of Defense, and the office of US congressman Alan Lowenthal of California. During the trip, TPP hosted a networking reception for students and alumni.

During the summer of 2016, TPP funding will support a student interning at the US Office of Management and Budget. Other TPP students are participating in paid internships at various agencies and corporations including ARPA-E (Advanced Research Projects Agency-Energy), Draper Laboratory, the Quality Council of India, and Amgen.

Conferences and Workshops

Over the past year, TPP students presented papers and posters at conferences and workshops around the world.

TPP is a founding member of the Technology Management and Policy Graduate Consortium, which includes programs in North America, Europe, and Asia. The annual meetings of this consortium afford TPP students and Engineering Systems Division

doctoral students the opportunity to share their research and network with students across the globe. More than 50 students and faculty from 11 universities typically participate in the event. This year's consortium meeting was hosted by the University of Cambridge in June 2016. Through the generosity of a private donor, TPP was able to provide travel funds for four TPP and Engineering Systems Division PhD students along with three TPP researchers and instructors. Amanda Giang (TPP '13), a PhD candidate in IDSS, won the best paper award at the event for "Leveraging Environmental Monitoring Networks for Policy Evaluation: Detecting Anthropogenic Mercury Emissions Changes in the Laurentian Great Lakes."

The annual MIT Energy Conference and MIT Energy Night leadership teams featured several TPP students. Our students are involved in leadership of a number of organizations and initiatives across the Institute, including the MIT Energy Club, the MIT Clean Energy Prize, the Science Policy Initiative, the Sustainability Initiative, Graduate Women at MIT, the Graduate Student Council, LBGT@MIT, MIT house committees, ESL tutors, Engineers Without Borders, and the Transportation Club.

Student Honors and Awards

TPP students received honors and awards from MIT and beyond. This year, students received MIT Clean Energy Prizes, MIT Sandbox Innovation Fund Program grants, a Legatum seed grant, a Fulbright Award, and a Best Paper Award at the IEEE International Systems Conference.

Student Society

Among the highlights of the year were the "Culture Nights" and the iAmbassador series, which offer international students an opportunity to give presentations about their culture and technology policy issues in their home countries. This year the student society continued to hold "Coffee Talks," which give students an opportunity to talk to each other about subjects of personal interest to them. Topics over the past year ranged from how to eat well on a graduate student stipend to tax evasion. The student society also hosted an alumni panel discussion and a TPP alumni-student mixer. Additionally, the annual "InterYear Retreat" continues to be one of the biggest events of the year.

40th Anniversary

The Technology and Policy Program celebrated its 40th anniversary with an event on May 20 that brought together TPP alumni and others from academia, government, and industry. The event was co-organized by Noelle Selin, TPP associate director and Esther and Harold E. Edgerton Career Development Associate Professor, and Jessika Trancik, Atlantic Richfield Career Development Assistant Professor. While TPP's 30th anniversary in 2006 focused on the rich history of the academic program, this year's event looked ahead to future opportunities and challenges. The daylong celebration included panels focusing on topics such as innovation, regulation, development and sustainability, and conflict and cooperation. A number of TPP alumni and other experts provided perspectives from their experiences working at the intersection of technology and policy.

Alumni Engagement

With more than 1,200 alumni, TPP continues to foster a strong alumni community. TPP alumni host students at their organizations during annual Washington, DC, visits. In addition, alumni have supported student and program initiatives including funding for summer internships, recruitment and outreach, and support for women in technology and policy.

Leadership

IDSS director Munther Dahleh is serving as interim director while the TPP faculty advisory board seeks a new program director. Noelle Selin is the associate director, and Frank Field serves as director of education.

Undergraduate Minor in Statistics and Data Science

IDSS understands that the need to analyze data in order to make informed decisions is fundamental to our society. As increasing amounts of data and more powerful computational resources become ubiquitous, statistics is an essential tool for almost every quantitative field.

As the home of MIT's emerging statistics community, IDSS is working to offer academic programs in statistics to MIT's undergraduate and graduate students. The first of these is MIT's new minor in statistics and data science. Through six required subjects, this program will provide students with a working knowledge base in statistics, probability, and computation, and help them develop their ability to perform data analysis. The program will begin in September 2016 and has already attracted 10 initial students.

Curriculum

As noted, six subjects are required to qualify for the minor in statistics and data science. The curriculum begins with one foundation subject and then advances to two statistics subjects (one each from Statistics 1 and Statistics 2) and finally two computation and data analysis subjects. After these subjects have been completed, one capstone subject will be taken by all students to complete the minor. As a means of offering flexibility with students' major program, students can petition the statistics minor oversight committee to take a more advanced graduate subject in place of the standard choices.

Research

IDSS takes a holistic and data-driven approach to analyzing complex, high-impact systems in society. IDSS research integrates systems thinking, state-of-the-art quantitative analysis, and an understanding of human and institutional behavior into its methodologies, aiming to address broad overarching challenges inherent to highly interconnected and data-rich systems. Specifically, IDSS research explores resilience and systemic risk, system design and architecture, sustainability and policy, and the data-to-decisions process. IDSS research labs and centers are described below.

Laboratory for Information and Decision Systems

The major research lab within IDSS, the MIT Laboratory for Information and Decision Systems is an interdepartmental research center committed to advancing research and education in the analytical information and decision sciences, specifically systems and control, communications and networks, and inference and statistical data processing. Throughout its history, LIDS has been at the forefront of major methodological developments in a wide range of fields, including telecommunications, information technology, the automotive industry, energy, defense, and human health. Building on past innovation and bolstered by a collaborative atmosphere, LIDS members continue to make breakthroughs that cut across traditional boundaries. See the LIDS report to the president for more information.

Statistics and Data Science Center

Statistics and data science are uniquely powerful tools across many disciplines represented at MIT, from economics and anthropology to computer science and environmental engineering. In 2015, the MIT Statistics and Data Science Center (originally the MIT Center for Statistics) was created within IDSS to formalize and consolidate efforts in statistics at the Institute. The center's mission is to serve as an MIT-wide focal point for advancing research and education programs related to statistics and data science by developing new academic programs in this field. See the Statistics and Data Science Center report to the president for additional information.

Sociotechnical Systems Research Center

The MIT Sociotechnical Systems Research Center is an interdisciplinary research center that focuses on collaborative, multidisciplinary, systems-theoretic approaches to complex societal challenges. SSRC comprises nine research programs, and its total research volume in FY2016 was approximately $9.7 million. See the Sociotechnical Systems Research Center report to the president for more details.

Munther Dahleh
Director
William A. Coolidge Professor of Electrical Engineering and Computer Science

Statistics and Data Science Center

Statistics, the science of making inferences and decisions under uncertainty, is increasingly relevant in the modern world due to the widespread availability of unprecedented quantities of data and computational resources. In particular, the need to process and manage massive amounts of data has become a key feature of modern statistics. This aspect of managing and processing data is popularly referred to as "data science."

Statistics and data science are a uniquely powerful tool across many disciplines represented at MIT—from economics and anthropology to computer science and environmental engineering. In 2015, the MIT Statistics and Data Science Center

(originally the MIT Center for Statistics) was created within the new Institute for Data, Systems, and Society, to formalize and consolidate efforts in statistics at MIT.

The center's mission is to serve as an MIT-wide focal point for advancing research and education programs related to statistics and data science by developing new academic programs in this field.

Leadership

Effective July 1, 2016, Professor Devavrat Shah of the Department of Electrical Engineering and Computer Science was appointed the center's first director. Additional leadership comes from members who represent some of the diversity of research foci embraced by the center. These include Emery Brown (Brain and Cognitive Sciences), Victor Chernozhukov (Economics), David Gamarnik (Management) and Philippe Rigollet (Math).

Minor in Statsitics and Data Science

September 2016 marked the launch of the undergraduate Minor in Statistics and Data Science, a six-subject curriculum whose final requirement is the new capstone subject IDS.012 Statistics, Computation and Applications.

The capstone subject is intended to provide a comprehensive study of the intersection between statistics and computation via hands-on data analysis. The course includes four modules each centered on a specific data set introduced by a domain expert. Potential modules may include medical data, gene regulation, social networks, finance data (time series), traffic, transportation, weather forecasting, policy, or industrial web applications. The goal is to provide instruction in specific, relevant analysis methods and corresponding algorithmic aspects. Subsequent projects will address large-scale data analysis questions.

Professional Education

Ninety percent of the world's data was created in the past few years. Faced with overwhelming amounts of information, organizations are often struggling to extract actionable insights. Data Science: Data to Insights is a new, six-week, online, professional education course set to launch in October 2016 focusing on analytics for data scientists, business analysts, engineers, and technical managers from startups to larger corporations.

Co-directed by Professor Devavrat Shah and Professor Philippe Rigollet, this Digital Programs offering incorporates streaming video instruction from MIT faculty across multiple departments. The curriculum comprises five modules that engage students with a variety of topics, including recommendation engines, regressions, network and graphical modeling, anomaly detection, hypothesis testing, machine learning, and big data analytics. The ultimate goal is to teach students how to apply data science techniques to effectively address organizational challenges.

Upon successful completion of the course, participants will receive an MIT Professional Education Certificate of Completion and Continuing Education Units.

Stochastics and Statistics Seminar

The Stochastics and Statistics Seminar is a signature series of weekly seminars hosted at MIT featuring top statisticians and data scientists from around the world.

Prior seminar topics have included:

Peter Bartlett (University of California at Berkeley): Efficient Optimal Strategies for Universal Prediction

Gábor Lugosi (Pompeu Fabra University): On a High-Dimensional Random Graph Process

Eric Tchetgen Tchetgen (Harvard University): Next Generation Missing Data Methodology

Roman Vershynin (University of Michigan): Discovering Hidden Structures in Complex Networks

Conference

The 29th Annual Conference on Learning Theory (COLT) was held this year at Columbia University. The conference was chaired by Professor Alexander Rakhlin, a visiting professor at IDSS, together with Dr. Vitaly Feldman of IBM Research. COLT is the leading conference on the theoretical foundations of machine learning and related fields, and home to the major advances in the field over the last three decades.

The quality of the papers this year was exceptional, with topics ranging from modern statistics and probabilistic modeling to optimization with large-scale data and understanding the power of deep neural networks. Such a breadth of topics is a hallmark of COLT, and well aligned with the interdisciplinary vision of IDSS. MIT had a sizable representation at the conference, with four out of the 63 accepted papers being co-authored by members of MIT.

Research Priorities

Alberto Abadie, Professor, Economics: Econometrics, Casual Inference, Program Evaluation

Guy Bresler, Bonnie and Marty Tenenbaum Career Development Assistant Professor, Electrical Engineering and Computer Science: Graphical Model Learning, High-Dimensional Statistics

Tamara Broderick, ITT Career Development Assistant Professor: Scalable, Robust Bayesian Inference and Graphical Models, Nonparametric Bayesian Models and Inference, Bayesian Unsupervised Learning

Emery Brown, Edward Hood Taplin Professor, Medical Engineering and Computational Neuroscience: State-space and Point Process Models of Neural Systems, State-space Models for Spectral Analyses, Tracking Brain States Under General Anesthesia

Victor Chernozhukov, Professor, Economics: Causal Inference using Machine Learning Methods, Central Limit Theorems in Very High Dimensions, Quantification of Uncertainty in High-Dimensional Inference

David Gamarnik, Professor, Sloan School of Management: Algorithms and Optimization in Stochastic Models, High Dimensional Statistics, Inference in Graphical Models

Stefanie Jegelka, X-Consortium Career Development Assistant Professor, Electrical Engineering and Computer Science: Combinatorial Distributions and Models in Statistics and Machine Learning, Convex and Combinatorial Optimization, Submodular Functions, Kernel Methods

Rahul Mazumder, Assistant Professor, Sloan School of Management: Modeling and Computation in Multivariate Statistics with Convex and Discrete Optimization, Statistical Methods for Low-Rank Modeling, Graphical Models, Variable Selection, Robust Statistics, Nonparametric Function Estimation

Anna Mikusheva, Associate Professor, Economics: Econometrics, Time Series, Uniform Inferences

Elchanan Mossel, Professor, Mathematics: Combinatorial Statistics, Discrete Fourier Analysis and Influences, Randomized Algorithms, Computational Complexity, MCMC, Markov Random Fields, Social Choice, Game Theory, Evolution

Whitney Newey, Jane Berkowitz Carlton and Dennis William Carlton Professor of Economics and Department Head, Economics: Semiparametric Estimation; Inference in Large Dimensional Models; Nonlinear Panel Data; Economic Model with Functional Heterogeneity.

Philippe Rigollet, MIT Assistant Professor, Department of Mathematics: High-Dimensional Statistics, Statistical and Computational Tradeoffs, Online Learning

Devavrat Shah, Professor, Electrical Engineering and Computer Science: Non-Parameteric Framework for Recommendation Systems, Inference and Graphs, Centralized Data Center Networks

Caroline Uhler, Henry L. & Grace Doherty Assistant Professor, Ocean Utilization; Electrical Engineering and Computer Science: Graphical Models and Causal Inference, Algebraic Statistics, Inferring Gene Regulatory Networks in Space and Time

Roy Welsch, Professor of Statistics and Management Science, Sloan School of Management: Robust Statistics and Data Mining, Inference for Sparse Estimation, Repurposing of Drugs

Devavrat Shah
Director, Statistics and Data Science Center
Professor, Electrical Engineering and Computer Science

MIT Sociotechnical Systems Research Center

The MIT Sociotechnical Systems Research Center (SSRC) is an interdisciplinary research center that seeks collaborative, multidisciplinary, systems-theoretic approaches to complex societal challenges. SSRC comprises nine research programs, and its total research volume in FY2016 was approximately $9.7 million.

SSRC began in FY2016 with Professor Ali Jadbabaie as interim Director. Professor Jadbabaie was then on sabbatical from the University of Pennsylvania, serving as a visiting scholar at MIT while conducting research in the Laboratory for Information and Decision Systems. Professor Jadbabaie's role ended in December 2015 and MIT Professor Munther Dahleh took his place for the remainder of the fiscal year. During his 14-month tenure, Professor Jadbabaie lead the integration of SSRC and IDSS, serving as interim associate director of IDSS while leading SSRC. Given Professor Dahleh's leadership at IDSS and because of SSRC's close relationship with IDSS, the leadership transition was smooth and effective.

Over the past year, SSRC brought in two new centers, the Center for Complex Engineering Systems led by Professor Oliver de Weck, and the Connection Science Center, led by Professor Alex (Sandy) Pentland. The inclusion of these two centers significantly increased SSRC's research volume.

SSRC administers research that brings together faculty, researchers, students, and staff from across MIT to study complex enterprises that span government, industry, the service sector, and healthcare. Primarily, SSRC supports IDSS faculty research, but we also support other partners, including the Center for Biomedical Innovation, the Center for Complex Engineering Systems, the Consortium for Engineering Program Excellence, the Ford-MIT Alliance, the MIT Information Quality Program, and the Systems Engineering Advancement Research Initiative. Below is a brief research summary outline for each of the centers within SSRC.

Center for Biomedical Innovation

The mission of the MIT Center for Biomedical Innovation (CBI) is to conduct collaborative research with real-world impact on our ability to deliver safe, high quality biomedical therapies to patients worldwide. Major initiatives in the past year include continuing efforts in bio-therapeutic manufacturing innovation, risk management of economically motivated adulteration of food and drug products emanating from the global supply chain, regulatory innovation in drug approval processes, and the launch of a new initiative focused on catalyzing the evolution of real-world evidence standards to drive greater value from big data in pharmaceutical innovation. All research at CBI involves the collaboration of multidisciplinary teams from across the Institute working together with manufacturers, regulators, payers, and other members of the global biomedical and healthcare innovation ecosystem in order to optimize the creation and implementation of innovative solutions to complex issues that often require consensus by multiple stakeholders.

CBI's mission is to improve global health by overcoming obstacles to the development and implementation of biomedical innovation. CBI provides a safe and transparent

environment for collaborative research among industry, academia, and government, and draws on the expertise of MIT's Schools of Engineering, Science, and Management, as well as the Harvard-MIT Division of Health Sciences and Technology.

Biomanufacturing Program

The Biomanufacturing Program (BioMAN) hosted two working group sessions during the past year, both of which were attended by all 10 member company representatives. In September 2015, the session was titled "Making Transformative Change in BioManufacturing." April 2016's the session was called "Product Quality Control for Protein Biotherapeutics."

In November 2015, BioMAN hosted its seventh annual summit meeting, Cell and Gene Therapy Products: Meeting the Biomanufacturing Challenges. This two-day event, featuring panel discussions and presentations by members of the biomanufacturing industry, the government, and MIT and other faculty, explored the manufacturing challenges of cell and gene therapy products, science and enabling technology for product safety, and the critical needs of sustainable commercial manufacturing. In addition, the meeting included a poster session highlighting cell- and gene-therapy related research, with prizes sponsored by CASSS, an International Separation Science Society.

BioMAN has also begun a global health initiative to expand access to biotherapeutics. Our goal is to work with interested parties to identify obstacles that systems engineering, critical thinking, and technology can address, and to encourage the technical community to contribute and share novel ideas and/or novel technologies to close defined gaps. To this end, in January 2016, BioMAN, in collaboration with CASSS, hosted a plenary workshop at the 20th Symposium on the Interface of Regulatory and Analytical Sciences for Biotechnology Health Products. The workshop aimed to provide a forum for researchers to discuss how CASSS and CBI can contribute to addressing a global need for pharmaceuticals, especially protein therapeutics. A lively discussion session followed presentations, with active participation from the audience. Questions and comments were raised in five overarching areas: cost of goods, non-technical factors, compliance challenges, regional focus, and potential advancements via science and technology. Both CASSS and BioMAN will map out follow-up plan and actions.

Consortium on Adventitious Agent Contamination in Biomanufacturing

The Consortium on Adventitious Agent Contamination in Biomanufacturing (CAACB Consortium) focuses on mitigating the risk of adventitious agent contamination in biomanufacturing through collaborative research between MIT and sponsors (25 biopharmaceutical manufacturers and technology and service providers). The consortium currently has four major projects, including an industry-wide assessment of viral contamination experiences, best practice in risk assessment, harmonization of media treatment data, and evaluation of the most effective and economic options available.

During the past year, CAACB hosted two workshops at MIT: one in October 2015, Facility Segregation; and another in April 2016, Contamination with Difficult to Detect Bacteria. The outcomes of the research projects were presented at the Bioprocessing Summit in August 2015; at the BioTalk Conference, ManUBio Leaders Summit, and

ISBiotech Conference in September 2015; at the Viral Clearance Symposium in October 2015; at the Vaccines Bioprocess and Commercialization workshop in May 2016; and at the Viral Safety in Biologics workshop in June 2016. Two white papers are forthcoming.

NEW Drug Development ParaDIGmS

MIT's NEW Drug Development ParaDIGmS, also known as the MIT NEWDIGS Initiative, is a unique collaborative "think and do" tank with a mission to enhance the capacity of the global biomedical innovation system to reliably, quickly, and sustainably deliver new, improved, and affordable therapeutics to the right patients. NEWDIGS fuels the design, testing, and implementation of sustainable patient-centered change, extending from bench to bedside.

NEWDIGS established worldwide visibility with its seminal "Adaptive Licensing Project," which developed the intellectual foundation that underpins a European Union–wide pilot program led by the European Medicines Agency (EMA), which launched in 2014. NEWDIGS continues to drive associated technical and educational activities as the only ex-EU partner in the ADAPT-SMART consortium of the Innovative Medicines Initiative (IMI). In June 2016, NEWDIGS and IMI co-hosted a two-day workshop held at EMA in London with over 80 multi-stakeholder participants focused on adaptive biomedical innovation. MIT CBI is credited with introducing this term and its corresponding paradigm to the global industry in 2016, and for highlighting the need for coordinated system-level advancements (policies, processes, infrastructures) to better support the scientific advancements of precision medicine.

Evidence generated from data sources beyond traditional randomized clinical trials (RCT) is becoming increasingly important in biomedical innovation in the era of precision medicine and value-based reimbursement models. The NEWDIGS data project focuses on addressing a number of challenges associated with the generation of data, and uses "integrated" evidence from RCTs and real world "big" data that will be acceptable to key decision makers in pharmaceutical innovation (especially regulators and payers). A workshop in October 2015 was attended by senior leaders from the National Institutes of Health (NIH), the US Food and Drug Administration (FDA), EMA, the Patient-Centered Outcomes Institute, as well as a number of health insurers and biopharmaceutical companies. The workshop explored research critical to an NIH award received in partnership with Johns Hopkins Medical Center and Tufts New England Medical Center for the establishment of a new, national (clinical) Trial Innovation Center.

In May 2016, NEWDIGS launched the FoCUS (Financing and Reimbursement of Cures in the US) Project with an invitational design lab featuring participants from across the downstream biomedical value chain. This initiative addresses the pressing need for innovative financing and reimbursement models for emerging curative medicines in the US. FoCUS will engage with MIT's Sloan School of Management and wit Professor Andrew Lo's Laboratory for Financial Engineering in activities that center around the design, rapid cycle prototyping, and piloting of up to four financing and reimbursement models for curative therapies in the US, with the first pilot launch targeted for 2017.

Educational Activities

CBI's BioMAN program received financial support from the Amgen Foundation to support the Amgen-MIT Biomanufacturing Educational Initiative, which allowed for the development of a massive open online course (MOOC) on biopharmaceutical manufacturing. 10.03x Making Biologic Medicines for Patients: The Principles of Biopharmaceutical Manufacturing launched on July 14, 2015, with approximately 7,000 learners, and again on October 27, 2015, with another 4,000 learners. This course connects engineering fundamentals to real-world applications, shows real pieces of biomanufacturing equipment in action, and has experts describe real-world engineering challenges.

Other educational initiatives include the MIT course 10.03/10.53 Advances in Biomanufacturing (10.03/10.53). Led by Professors J. Christopher Love, Anthony Sinskey, and Dr. Stacy Springs, the course (offered in both fall 2015 and spring 2016) focuses on how biopharmaceutical therapeutics are manufactured and delivered. This course is run in blended format, with students learning the principles of biomanufacturing online in 10.03r, and going in depth with guest lecturers, including regulators and subject-matter experts from industry.

In addition, MIT CBI co-organized a Vaccines Bioprocess and Commercialization workshop with University College London in May 2016. This three-day workshop explored critical issues at the various stages of vaccine development. With contributions from MIT, University College London, and the Jenner Institute, as well as international industry experts from Pfizer and MedImmune (among others), attendees developed their understanding of the research and operational and regulatory challenges of the vaccine market.

Sponsored Research Projects

This is our third year of our project, Addressing Non-traditional Adulteration of FDA-regulated Food and Drug Products and Ingredients Emanating from the Global Supply Chain. The project, funded by the FDA, is a collaboration between faculty, staff, and students from the Sloan School of Management, the Computer Sciences and Artificial Intelligence Lab, and CBI. Our work focuses on China, the US's third largest source of food imports. The analysis and findings of this project suggest that supply-chain and product-related characteristics can be used to effectively predict and assess risk at the product/supply chain level, as well as at the firm/site level. We have ample evidence that the FDA could significantly improve its capabilities of addressing and managing risks related to adulteration of food products by making major investments in building organizational capabilities in order to obtain improved visibility into relevant food supply chains and to better understand their dynamics. Paula (Gigi) Hirsch is the executive director of CBI.

The Center for Complex Engineering Systems

The Center for Complex Engineering Systems (CCES) is based jointly at MIT and the King Abdulaziz City for Science and Technology (KACST), Saudi Arabia's national science agency. Since its 2011 inception, CCES has been part of KACST's Joint Centers of Excellence Program. The core mission of the Joint Centers of Excellence Program is to

foster the necessary research environment to improve the competitiveness and capacity for innovation through scientific inquiry, and to participate in a rigorous training program for the most promising young scholars who are selected from the top 0.5% of applicants from across the Kingdom. Among the 14 joint centers across the globe (including Stanford University, Oxford University, and others), CCES's productivity stands out, with very high research outputs and acceptance yields to top-tiered schools of engineering. Moreover, the center's spirit of interdisciplinary and interpersonal collaboration make the partnership between MIT and KASCT highly rewarding.

In 2016, CCES's fifth year of operations, the center's growth and impact solidified and matured. In fall 2015, the center launched six new research projects, many of which are expansions in scope of previous projects. These include research focused on energy management at the urban, national and regional scale; on the integration and optimization of transportation networks; on the expansion of the innovation space within the Kingdom's economy and technology policy; and on developing platforms for integrating decision support systems that leverage interconnected aspects of findings across CCES's portfolio. The third cycle of two-year research projects builds upon the scholarship of past cycles, and many of the principle investigators on CCES projects are also leading a second or third project. This commitment on behalf of the faculty to invest their time and mentorship has been acknowledged and admired by KACST. Currently 14 MIT faculty members from across seven academic departments make up the roster of principal investigators on CCES projects. The number of research affiliates has also grown significantly in both Cambridge and Riyadh. Nearly 100 students, research affiliates, and postdocs are members of CCES.

In 2016, CCES maintained and deepened relationships in its network which is comprised of more than 20 organizations, including the Ministries of Labor, Economy and Planning, and Water and Electricity, as well as the Arriyadh Development Authority. Our relationships allow for access to an unusually wide array of data, which enriches the quality of the research.

Stakeholder relationships are further enhanced by collaboration with leaders from other institutions of higher education in Saudi Arabia, such as the King Abdullah University of Science and Technology, the King Saud University, and the King Fahad University of Petroleum and Minerals. In 2016, Professors Olivier de Weck (from the Department of Aeronautics and Astronomics), and John Williams (from Civil and Environmental Engineering), inspired by similar successful programs at MIT, worked in an advisory role to help Alfaisal University establish a new master's program in engineering and systems management for students with previous experience in industry. CCES leadership and faculty have also participated significantly in the development of the most recent National Science and Technology Innovation Plan, a five-year plan for investments in education and technology which forms the roadmap for the Kingdom's transition to a knowledge-based society. Earlier in 2015, Professors Olivier De Weck and Cesar Hidalgo (Media Lab) contributed substantive recommendations to a report that was eventually adopted by the new administration in 2016, and incorporated in the newly released Vision 2030 report for future investments in the Kingdom.

To date, CCES-funded affiliates have authored or co-authored approximately sixty publications, including works in progress destined for peer-reviewed journals and leading conference venues. A large percentage of these publications have been jointly authored by CCES researchers based both at KACST and MIT, demonstrating the fruits of our international collaboration. Links to these articles, as well as biographical information about our affiliates, can be found on the CCES website. Some highlights of this output include the July 2016 award for best paper at the INCOSE International Symposium in Edinburgh, Scotland for "*Insight for desalination for agriculture in Saudi Arabia*", which emerged from the Strategic Solar Desalination Network project (concluded June 2016). CCES is led by Professor Olivier de Weck.

Consortium for Engineering Program Excellence

The Consortium for Engineering Program Excellence's (CEPE) fundamental and collaborative applied research efforts focus on improving program performance by examining the relationships and interactions between diverse functions and stakeholders involved in complex engineering programs. The research is framed through the lenses of the program management, systems engineering and product development, lean management, and organizational change fields. Its strategic partners in this work are the Project Management Institute and the International Council on Systems Engineering (INCOSE). In July 2015, CEPE presented research findings from its study on the integration of program management and systems engineering at the INCOSE International Symposium in Seattle, WA, and at the Global Teamwork Laboratory Symposium in Tokyo, Japan, in October. A book manuscript that captures the insights from the integration study is in the final stages of completion, with the resulting publication expected in mid-2017. During this period, four CEPE-advised master's theses were completed and another three were begun. Two journal papers were published, and six conference papers were presented, with four more accepted for presentation in the next reporting period.

Professor Warren Seering is CEPE principal investigator and Dr. Eric Rebentisch is research lead.

Ford-MIT Alliance

The Ford-MIT Alliance, an Institute-wide initiative, was established in 1998. In 2013, the Alliance began a fourth phase that will renew automatically each year for the foreseeable future. The Alliance is the Institute's longest running large-scale collaboration with industry. Since 1998, the Alliance has funded more than 150 projects across the Institute with a total investment to date by Ford of more than $50 million. The Ford-MIT Alliance research portfolio is managed by an operating committee that includes two co-directors: Professor Jonathan How of MIT and Ed Krause, Ford's global manager of external alliances in their Division of Research and Advanced Engineering. This group reports to an executive committee that includes Associate Provost Karen Gleason and Ken Washington, the vice president of research and advanced engineering at the Ford Motor Company. The alliance holds executive committee meetings on campus at least once annually. This year, the alliance had a record number of participants from the MIT faculty.

MIT Information Quality Program

The MIT Information Quality (MITIQ) Program focuses on pragmatic solutions to information quality (IQ) problems related to the collection, storage, and use of data in enterprise systems. Research continues on the roles, responsibilities, and function of the chief data officer. MITIQ conducts research in the financial, health care, and technology industries, and in government and military organizations, focusing on emerging trends, technologies, and policies. Research has also investigated the application of semantic technology to the integration of unstructured, semi-structured, and structured information to trade space-decision analysis for defense capability requirements. Research on semantics of data in the financial industry addresses questions of formal semantic information integration in support of systemic risk regulatory mandates. Cybersecurity research builds on MITIQ methods for mapping the flow and control of information through extended enterprises. Issues addressed in these settings parallel concerns in many other areas in government and private industry.

During the year, MITIQ sponsored the 4th annual Chief Data Officer Forum in Arlington, VA, and along with with SSRC the 8th annual Chief Data Officer and Information Quality Symposium on the MIT campus. Both events focused on information quality and data science. Dr. Rich Wang is the MITIQ director.

Other Selected Research

In FY2016, one of SSRC's largest single research efforts, the MIT Post-Traumatic Stress Innovations project, came to a close. Following four full years of research staffed by four faculty, five PhD researchers, and eight student research assistants, this project was well received by the sponsors, the US Army Medical Research and Materiel Command in cooperation with the leadership of the military health system. The project used social science methodologies and strategic analysis of organizations to examine the continuum of care for service members and their families affected by post-traumatic stress, and focused on organizational policies, structures, processes, technology, information and resource flows, and stakeholder relationships. In its final year, this project was led by Professor Thomas Kochan.

MIT, along with six other universities, is a member of a partnership with the United States Agency for International Development (USAID) to help alleviate poverty in the developing world through the use of science and technology. There are two major components of this partnership; the Comprehensive Initiative on Technology Evaluation (CITE), and the International Development Innovation Network. CITE evaluates technologies to help donors and policy makers pursue the best solutions for challenges in the developing world. SSRC is part of this groundbreaking interdisciplinary effort. This research is led by Professor Olivier de Weck.

MIT Connection Science

Professor Alex "Sandy" Pentland's MIT Connection Science research initiative continued to pursue funding for research that utilizes communications networks to access and change real-world human behavior. As a further step in that direction, Professor Pentland brought the Kerberos Internet Trust Consortium from its former home in MIT

Information Systems and Technology to SSRC under the new moniker, the Internet Trust Consortium (ITC). In SSRC, the ITC has continued with its mission to "develop open source components for the Internet's emerging personal data ecosystem in which people, organizations, and computers can manage access to their data more efficiently and equitably." The ITC is a multi-sponsor consortium.

Systems Engineering Advancement Research Initiative

Several research projects continued with government agencies in the US, the Naval Postgraduate School, Draper Laboratory, and the Norwegian University of Science and Technology. The Systems Engineering Advancement Research Initiative (SEAri) leads MIT's continuing participation in the US Department of Defense University Affiliated Research Center, or Systems Engineering Research Center (SERC). SEAri is actively engaged in collaboration with other universities involved in the SERC research program, such as the Georgia Institute of Technology, the University of Southern California, and the University of Virginia. Ten graduate students (both master's and doctoral level) from several degree programs performed research with the group.

SEAri published and presented seven conference papers and three government reports, published two co-authored book chapters, and presented three invited talks. SEAri received the annual Best Paper Award for the 2016 IEEE Systems Conference, and the Best Systems Engineering Research Transition Paper Award for the 2016 Conference on Systems Engineering Research.

Dr. Donna Rhodes is SEAri principal investigator and Dr. Adam Ross is a collaborating research scientist.

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JR East Professor of Engineering