Department of Civil and Environmental Engineering

The Department of Civil and Environmental Engineering (CEE) operates at the nexus of science, engineering, infrastructure, and the environment, an approach termed "big engineering." Big engineering begins with the necessary understanding at the micro level to achieve solutions that will help society at the macro level: building more sustainable infrastructure, mitigating climate change effects on land and people, and preserving and protecting global resources. We aim to leverage small-scale change that leads to large-scale global impacts.

The department's accomplishments continued to grow during the 2015–2016 academic year. Our gains are evident in our enhanced educational programs, new and transformative research advancements, and local, regional, and global gains in recognition. We are solidifying our leadership in many areas related to the world's grand challenges regarding infrastructure, the environment, and people, including ecological systems, resources and sustainability, structures and design, urban systems, and global systems. We are leveraging opportunities to complement our current faculty roster with new hires who have the cross-disciplinary talents, experiences, and skills necessary to define civil and environmental engineering in the 21st century.

Our students bring unconventional ways of thinking about traditional problems, infusing new approaches and insights to existing challenges and opportunities. We work with students in the classroom, in the field, and in labs to innovate and scale discoveries from the nano level to the global level as a means of improving people's lives and conditions. We believe that the department's research and education will shape lives today and in the decades to come, led by our alumni.

Our vision is one of an integrated department whose people work to solve previously unsolvable big engineering challenges. A series of seven new powerful images with key messages were posted around campus over several months to heighten awareness of how CEE research and education apply to society's critical needs. We experimented with new ads in the student newspaper, and we increased our presence on popular social media channels. By launching a recurring email communications campaign this past spring, we also targeted MIT freshmen with specific outreach and events designed to strengthen interaction and engagement with and understanding of our goals and mission.

CEE's impacts are already being felt across several strategic research areas. For example, new junior faculty in the Ralph M. Parsons Laboratory for Environmental Science and Engineering have extended our understanding of complex land and ocean ecological systems, providing valuable insight into these dynamic ecosystems to spur engineering and policy innovation. In addition, research conducted in the Henry L. Pierce Laboratory for Infrastructure Science and Engineering, as well as remote fieldwork, is helping students learn to build more resilient and sustainable structures and urban systems.

Our cross-disciplinary research culture also links seemingly disparate projects, such as Professor Benedetto Marelli's use of silk fibers to preserve fresh fruit longer and other research focusing on optimal mechanical devices to effectively coat the fruit. Everyone

working across boundaries toward broad-scale solutions is the best way to ensure that innovation will keep pace with civilization's current and emerging needs.

Additional progress has been achieved in the department's identity and messaging, new educational programs, new events, symposiums, and other initiatives.

Realizing a new, more broadly empowered vision and a redefined civil and environmental engineering profession will require continued efforts. Our role as educators must anticipate these realignments, and we must give students a deep and broad learning experience so that they have a solid foundation. This commitment is reflected in the core mission of the department to educate at all levels, from undergraduate to postdoctoral.

Our new Course 1 undergraduate program established in 2014 incorporates civil, environmental, and systems engineering education into a single program known as 1-ENG. The program features increased flexibility, allowing students to fulfill Institute and department requirements while encouraging personalization of tracks that best match career interests. Most recently, building on the development of our new program, the department submitted a request and received approval this spring to offer three new minors—in civil engineering, environmental engineering science, and civil and environmental systems—in fall 2016.

The department strives to lead by example and help set new civil and environmental engineering standards for other academic institutions, industry, and society. We continue to seek new ways to enhance our curricula and student experiences.

Selected department highlights from the past year include the following:

- CEE kicked off the 2015–2016 academic year with the launch of a new department logo at the registration day barbecue. In a message to the community, Head and McAfee Professor of Engineering Markus Buehler wrote that the logo reflects a "new, Department bold, leading, and inspirational vision" for the department. "Connoting energy and movement, our refreshed logo represents our history, while also setting us on a track for the future." The refreshed graphic identity is helping shape other visual communications in the department, including a new website under development and new print and digital materials.
- Business Insider named Associate Professor Colette Heald one of the 12 "most impressive professors" at MIT. Number two on the publication's list, Heald was celebrated for receiving the 2015 James B. Macelwane Medal and participating as a speaker at the 2015 World Economic Forum in Davos, Switzerland.
- On September 21, Professor Buehler and Chancellor and CEE professor Cynthia Barnhart represented the department at Boston: Sink or Swim, an event hosted by the Boston Athenaeum. The event featured an MIT faculty panel that discussed the impacts of climate change on people's lives, specifically what needs to be considered to protect Boston and surrounding areas from rising sea levels and

increasing major storms. The Athenaeum, a membership-based private library, is one of Boston's most historic and renowned intellectual and cultural institutions.

- The department, under the direction of faculty host Colette Heald, hosted the inaugural CEE Rising Stars Workshop on October 15–16. The workshop attracted 20 top early-career women in civil and environmental engineering and related fields from across the country who are interested in faculty careers. Participants had an opportunity to present their research as well as attend panel discussions with CEE professors and other MIT faculty focused on issues related to navigating the early stages of an academic career.
- The department hosted the third annual CEE New Research Alumni Breakfast on October 21; the theme of this year's event was environment, infrastructure, and people. Department Head Buehler opened the breakfast with a review of the various grand challenges present in society today and the steps those in CEE are taking to solve them. Professors Ben Kocar, John Ochsendorf, Admir Masic, Martin Polz, and Lydia Bourouiba all made presentations on their research.
- On November 20, CEE hosted the Infrastructure Innovation in a Changing Environment Conference, which explored diverse economic opportunities and market-driven responses to the challenges facing large-scale infrastructure projects. In collaboration with MIT's Industrial Liaison Program (ILP), leaders from industry, academia, and the public sector discussed the impact of issues ranging from budding infrastructure and population growth to the emergence of big data, new transportation technology, advanced energy sources, and security. CEE students also had the opportunity to showcase their research posters, soliciting important discussions and feedback.
- In the fall semester of 2015, the students enrolled in 1.101 Introduction to Civil and Environmental Engineering Design, under the direction of Professor Pedro Reis, were divided into four groups to design real-world solutions to Boston-area problems. The resulting projects included: (1) increasing energy generation using the aerodynamics of passing vehicles driving through a tunnel, (2) designing a sound-dampening wall near a freeway, (3) constructing a light well for a new dorm, and (4) studying wind tunnel effects in urban layouts.
- In June, CEE and MIT Professional Education offered a new short course, Agriculture, Innovation, and the Environment. The instructors included Professors Martin Polz, Lydia Bourouiba, Benedetto Marelli, Ben Kocar, Daniel Cziczo, Dennis McLaughlin, Ruben Juanes, and Markus Buehler from CEE; world-leading MIT researchers such as Abel Sanchez and Ross Alter; Institute Professor Robert S. Langer; John Lienhard, director of the Abdul Latif Jameel World Water and Food Security Lab (J-WAFS); Roger Beachy, chief scientific officer of the start-up company Indigo; Cameron Dryden of AOA Xinetics, a Northrop Grumman business unit; Ken Sudduth of the US Department of Agriculture (USDA); and Daniel Schmoldt of the National Institute of Food and Agriculture. The new course focuses on three areas of agricultural innovation: macro/micro aspects of environmental impacts, application of advanced technologies in agricultural processes, and use of data and modeling to enhance precision and predictive power.

- CEE alumnus Nicolas Chammas SM '87, who lives in Lebanon, has been named president of the MIT Alumni Association. Both he and Chan Rogers SM '51 were profiled in the July/August issue of the MIT Technology Review.

New CEE social media channels—LinkedIn, Facebook, Instagram, YouTube, and Twitter—are enabling greater dialogue and engagement with many other audiences, especially students and prospective students. The department head has his own Twitter handle (@ProfBuehlerMIT) and uses his tweets as an innovative way to communicate with students, faculty, alumni, and other stakeholders. More details about our social media channels are provided below.

Goals, Objectives, Priorities

The Civil and Environmental Engineering Department has made great progress this past year in realizing the full potential of a more integrated and enhanced program. It is experiencing a transformation similar to the major disruptions of the 1960s and 1980s when the introduction of computation, and then environmental science, genomics, and microbiology, influenced its direction.

Our students continue to change the world, while they are here and all during their careers. From alumni entrepreneurs desalinating ocean waters to engineers designing more resilient, sustainable, and energy-efficient cities, MIT is redefining what it means to work in this increasingly comprehensive field. Other institutions may continue to teach practitioners while we prepare new generations of global thinkers and doers. Working together across disciplines and educational and experience levels, our students, faculty, and researchers address the many questions and challenges civilization faces today.

As engineers, we continue to build, but our direction is now better informed by discovery and innovation at nano levels. Data characterization, modeling, and analysis also have lent new insights to our work, allowing design experimentation to be accomplished in hours as compared to what would have previously taken days, weeks, or months. New tools and instruments, such as high-powered Raman spectroscopy, along with renovated and newly created lab spaces increase our capacities. Collaboration with other scientific and engineering disciplines brings its own rich set of rewards, allowing many types of new research paradigms and relationships.

CEE's five strategic objectives remain the same as we continue our important work and build upon past accomplishments. This report articulates our advancements during the 2015–2016 academic year with respect to each objective.

- Objective 1: Renew, develop, and implement inspiring educational programs at the undergraduate, graduate, and postdoctoral levels
- Objective 2: Establish effective administration, facilities, and community
- Objective 3: Focus on the future of CEE with accelerated faculty hiring and junior faculty development
- Objective 4: Show leadership in MIT-wide initiatives by engagement across the Institute, defining a clear positioning of CEE at MIT
- Objective 5: Enhance alumni engagement and resource development

At its fall 2014 meeting, the visiting committee endorsed the department's new direction and initiatives under the leadership and vision of Markus Buehler. New faculty hires, increased philanthropic support, and new programs and communications are key core components.

Objective 1: Renew, develop, and implement inspiring educational programs at the undergraduate, graduate, and postdoctoral levels

Over the past academic year, 239 students were enrolled in CEE (56 undergraduates and 183 graduate students/doctoral candidates). The department awarded 16 PhD, 8 SM, 25 MST, and 19 MEng degrees in the graduate program and 25 SB degrees in the undergraduate program. Of the 16 PhD graduates, approximately two thirds are proceeding to careers in academia.

Undergraduate Programs

The 2015–2016 academic year saw the second full-year cohort of students in the department's 1-ENG bachelor of science degree program. The new 1-ENG undergraduate program is a comprehensive curriculum that better prepares graduates for their professional lives while still emphasizing a strong foundation in math, computation, probability and statistics, data analysis, and design. In compliance with the Accreditation Board for Engineering and Technology (ABET) curriculum accreditation procedures, the department this year submitted its formal application for program accreditation.

Changes to the curriculum this year included a revamped 1.101 Introduction to Civil and Environmental Engineering, reimagined by Professor Pedro Reis to align with Boston mayor Martin Walsh's "Imagine Boston: 2030" theme, and the addition of 1.007 Big Engineering: Small Solutions with a Big Impact, a new freshman seminar topic taught by Professor Benedetto Marelli. The latter class exposed freshmen to career opportunities available to CEE graduates and invited alumni to talk about their experiences as entrepreneurs in areas such as renewable energy, sustainable design, and transportation.

The 1-ENG program prepares students for today's jobs as well as emerging new positions such as chief resilience officer, 3D infrastructure engineer, urban agriculturist, and global system architect. Class discussions in 1.007 showed that students studying civil engineering leaned toward careers in innovating structures, architectural design, material testing, promotion of net zero energy buildings, sustainable infrastructure, and geo-technology. Environmental engineering students expressed interest in exploring bio-remediation, atmospheric modeling, hydrology modeling, pollution control, enhancing food security, and mitigating climate change. Finally, systems engineering cohorts gravitated toward applications in biological networks, traffic and transportation engineering, carbon sequestration, city planning, and mitigating infectious diseases.

Professor Admir Masic, in conjunction with Professors John Ochsendorf and Oral Buyukozturk, was eager to have a student cohort move into the field to learn first-hand about the sustainability of art, archeology, and architecture over time and against the threats of nature. The team, including 14 undergraduate and graduate students who will continue their research through a new fall 2016 special subject (1.S993 Heritage Science and Technology), conducted Materials in Art, Archaeology and Architecture

(ONE-MA3) fieldwork in Italy in June and July. The faculty and students traveled to Privernum, Pompeii, and Turin for this unique in-field, hands-on opportunity to research the complexities of long-term preservation strategies and techniques.

The CEE Student Association's new leadership incorporated new approaches to student outreach this year by designating representatives around each of the undergraduate cores for students to connect with, as well as by hosting freshman dinners and study breaks. In addition, the newly elected leadership has increased ties with the department, including implementing weekly meetings with Academic Programs Office (APO) administrators and twice-per-term meetings with the department head.

Over the past year, the senior capstone class (1.013 Senior Civil and Environmental Engineering Design) featured diverse research projects supported by multiple CEE faculty. Amanda Parry '16 received a senior capstone prize for her research on bridge abutments, and Olivia Massey '16 received a capstone prize for her research into sustainable ways to feed the global population.

Building on the success of last year's unique mini–Undergraduate Research Opportunities Program (mini-UROP), the department again hosted 18 freshmen during the 2016 Individual Activities Period (IAP). In the program, spearheaded by Course 1 graduate students, graduate students and postdocs are paired individually with freshmen, and the mini-UROP students work at least 30 hours per week in direct research over IAP. As a result of their interest and progress in their projects, almost half of the participants continued on as full UROP students during the spring term.

This year as the program has evolved, the organizers quickly realized opportunities to extend program benefits to include not only course credits but also new ways to build community. For example, new projects were added to build the students' hard science and engineering skills, and other new activities were built in to develop soft skills such as collaboration and networking and help improve students' mentoring skills.

In another significant initiative this past year (as noted above), the department received approval to offer three new minors (civil and environmental systems, environmental engineering science, and civil engineering) that will debut in fall 2016. The minors are expected to attract MIT students who are majoring in disciplines outside civil and environmental engineering but want to enhance their career path with complementary knowledge and experience.

Each minor consists of a set of subjects designed to deliver knowledge in core areas. According to CEE Student Association president Tiffany Wang, a rising senior, "It's great to see the new curriculum updates in Course 1. These new minors seem like a great way for students in other majors to incorporate their undergraduate programs with the domains of civil, environmental, and systems engineering, and it brings more variety of backgrounds into the department."

The civil and environmental systems minor combines principles and knowledge from across civil, environmental, and systems engineering into a hyper-concentrated program focused on both the built and natural worlds. In the environmental engineering science

minor, the popular Traveling Research Environmental Experiences (TREX) fieldwork during IAP is a program requirement, and ecology, microbiology, and water resources subjects are also included. The civil engineering minor offers subjects that reflect the wide extent of education that now encompasses the field, including solid and fluid mechanics, materials, structural mechanics, and labs.

Graduate Programs

CEE's graduate education programs also saw changes, improvements, and several new activities over the past year. Professor John Ochsendorf and Professor Elfatih Eltahir, associate department head, assumed leadership of CEE's MEng program. In addition, new ways to support graduate student and doctoral candidate initiatives were introduced, including increased departmental sponsorships of events and activities. Staff and faculty also volunteered to serve as judges at competitions and promote initiatives. For example, CEE became the primary sponsor of many of the MIT Water Club's events last year, including its annual Water Summit (Thriving with Change) held in November. "Workshops such as this are critical to raise awareness and build momentum towards solving the grand water challenges of our world," said Professor Eltahir, who participated in the event.

Assistant Professor Benedetto Marelli served as a judge at the MIT Energy Hackathon (also in November), which was co-led by CEE doctoral students Jessica Bryant and Thomas Petersen. According to Professor Marelli, "It has been very formative to watch how the participants have applied orthogonal thinking and independent acquisition of new knowledge to hack the different challenges."

Talks on REliable Environmental Science (MIT-TREES) is another student-driven organization that has developed a unique partnership with CEE. TREES identified a growing public interest in environmental topics such as climate change and air, water, and soil pollution and responded by producing short videos to illustrate scientific concepts in a creative, easily consumable form. The department's APO and communications staff work closely with TREES representatives during scripting and production to ensure scientific accuracy and relatability for lay audiences.

As mentioned above, the successful reprisal and enhancement of the mini-UROP program held over IAP would not have been possible without the leadership of the graduate students who set up the program with the assistance of the CEE APO administrators.

Our graduate committee (GradCom), along with other graduate students in the CEE community and CEE faculty and staff, worked closely together during this past year in developing stronger relationships with the department head and tapping mutual resources for improved program delivery and support.

Postdoctoral Program

CEE's postdoctoral committee has continued its path of success, providing a forum for discussion and involvement with the approximately 70 postdoctoral researchers in the department. The committee has made great progress in understanding and addressing

the professional and career development needs of postdoctoral researchers, identifying and improving mentoring opportunities, providing the researchers with opportunities to contribute to the department's educational programs, and enhancing their MIT and CEE experience. In addition to workshops and seminars geared toward the specific needs of postdoctoral scholars, a CEE postdoctoral social committee was formed to enhance opportunities for networking among faculty, postdoctoral scholars, graduate students, and staff.

Specific activities included once-a-semester town halls with the department head, a series of "lunch and learns" on topics of interest to postdoctoral researchers (e.g., web presence, publishing, digital education), and networking events for CEE postdoctoral researchers and faculty members. Also, there are new plans for a postdoctoral research day in March 2017, and teaching fellowships are available that allow postdoctoral researchers to be involved in teaching and education as part of their career development.

Postdocs have also contributed to CEE teaching activities through the postdoctoral teaching fellows program. This program has been very successful for postdocs, faculty, and students alike, and it has provided valuable training for our postdocs.

Objective 2: Establish effective administration, facilities, and community

The administrative staff continues to evolve and engage with all communities, including current and prospective students, their parents, faculty, other MIT faculty and staff, external peers, alumni, and news media. We accomplish this outreach through speaking engagements, seminars, listening tours, faculty forum webcasts (one each by Professor Markus Buehler and Institute Professor Sallie "Penny" Chisholm), town halls, coffee hours, stories in print and online, and other activities. Additional accomplishments and events are listed elsewhere in this report.

The department strengthened the collaboration between its two laboratories, the Ralph M. Parsons Laboratory for Environmental Science and Engineering (Building 48) and the Henry L. Pierce Laboratory for Infrastructure Science and Engineering (Building 1). The Parsons Laboratory focuses on natural systems and on understanding and engineering human adaptation to a changing environment. The Pierce Laboratory engages in science and engineering research critical to improving living conditions for humankind, advancing the innovation of materials, transportation systems, cities, and energy resources. This increased interaction continues to bind the disparate locations and was apparent at many formal and informal gatherings throughout the year. Some examples included remote live streaming of the Boston: Sink or Swim event in both labs; our internal CEE Research Speed Dating event, led by Pierce Laboratory assistant professor Admir Masic and Parsons Laboratory assistant professor Otto X. Cordero; and the CEE open house, during which a unique "CEE passport" was used to help campus visitors tour our demonstrations and activities.

CEE continued to refine its strategic focus around five challenge areas: ecological systems, resources and sustainability, structures and design, societal systems, and global systems. Our research and education within and across these strategic objectives are imperative to help create a better world and improve lives.

MIT Context for the Role of CEE

The department's intellectual focus is discovery and innovation to sustain life and society in changing conditions. CEE's two research labs, the Pierce Laboratory and the Parsons Laboratory, conduct research designed to better understand and solve the grand challenges of our time, from problems created by human activity to those that exist as natural systems. Our contributions are at the core of new products and applications that are being developed today in agriculture, wetlands management, renewable energy, sustainable structures, and large-scale systems design. The Department of Civil and Environmental Engineering is committed to playing a central role to support MIT's leadership in these domains.

Our long-term objective in the area of infrastructure, implemented in the Pierce Laboratory, is to become a center of excellence in the design, manufacturing, and operation of infrastructure. In September 2015, Associate Professor Ruben Juanes was named the new director of the Pierce Laboratory. Juanes's vision and expertise will benefit the laboratory's focus on using innovative science and engineering approaches to advance the design of infrastructure materials, transportation systems, cities, and energy resources.

Through our faculty's diverse expertise and collaborations with others, CEE addresses issues that are critical to society and the environment, such as infrastructure sustainability, resilience to catastrophic events, durability, and improved energy management. We made significant progress on a priority identified last year, that of applying radically new approaches to the design and manufacturing of infrastructure materials. New CEE faculty hires including Assistant Professors Admir Masic and Benedetto Marelli are already advancing research and education in this area, highlighting both the department's and MIT's thought leadership and impact.

Our long-term objective in the area of the environment, implemented in the Parsons Laboratory, is to engineer human adaptation to a changing environment. Human activities are affecting the global environment at historically high rates, and the effect of these changes on people and the environment is not known at present. Working from very small discoveries to large-scale solutions, researchers in the Parsons Laboratory aim to better understand global environmental changes in water, agriculture and food, species evolution and coexistence, environmental quality, natural hazards, and public health, among other areas.

In terms of advances made this year, Professor Elfatih Eltahir received national and international publicity for his research showing that people living in some parts of the Middle East might someday need to relocate because regional temperatures could become unsustainable. He also presented the keynote address this spring at a Massachusetts Department of Public Health regional symposium about migration patterns and ecological conditions that help or hamper the spread of disease, including viruses such as Zika spread by mosquitoes. Such timely and topical research is critical to the ways in which others view our work. Another example involves one of our newest faculty members, Serguei Saavedra. Within his first month at CEE, Saavedra held a quantitative ecology symposium on campus to convene researchers and professionals

in the Boston area and region interested in advancing work on this important, and previously under-recognized, topic. The conference room was so full that larger venues are now being sought for all future sessions—another sign that others are eager for CEE's and MIT's insight, direction, and leadership.

Laboratory Renovations

The tremendous accomplishments in the department over the past year are also present in our efforts to upgrade and improve our laboratories and facilities. We have successfully completed renovations to include state-of-the-art laboratories and work space in both the Pierce Laboratory (Building 1) and the Parsons Laboratory (Building 48). For example, renovations have been made to the Fluid Dynamics of Disease Transmission Laboratory, the Masic Laboratory, and the Marelli Laboratory in Building 1 and to the Atmospheric Chemistry and Composition Modeling Laboratory and the Eltahir Research Laboratory in Building 48.

The Fluid Dynamics of Disease Transmission Laboratory, a biological laboratory in the sublevel of Building 1, has been completed and is currently in the commissioning phase. This laboratory supports a junior faculty member, Assistant Professor Lydia Bourouiba, and anticipated future needs for departmental growth in biological areas. The laboratory houses facilities that allow biological and health-related research to be conducted within CEE's physical space. This new lab not only brings a unique biological and health research direction rooted in physical science and fluid dynamics to the main campus but also allows for broader biological work to be initiated within the confinements of the more traditionally civil engineering–oriented branch of CEE. A space previously rendered useless and unfit for occupancy of any kind is now a vibrant, active learning environment.

During fall 2015, the department renovated old and outdated laboratory space on the third floor of Building 1 to accommodate the Masic Laboratory. Within weeks of the project's completion, our newly hired junior faculty member Admir Masic acquired a confocal Raman microscope customized according to his own expertise and specifications. This device has already yielded extraordinary opportunities by enabling the faculty and surrounding CEE and MIT communities to capitalize on the groundbreaking techniques it affords. Professor Masic's laboratory will enable investigation of the structural and mechanical properties of biological materials.

In addition, after a much-needed renovation, the Atmospheric Chemistry and Composition Modeling Laboratory of Professor Colette Heald is now a cutting-edge computational facility that supports students and research staff who extract and model large data sets from various sources. Expansion plans for this laboratory include adding rooftop sensors and monitors to collect, feed, and display real-time data. The modular space includes lean/green features and functional furnishings.

Another computational renovation is under way for the Eltahir Research Laboratory, which has been challenged with an aging infrastructure and asbestos, as is much of the CEE community's space. This renovation will allow the Eltahir group members to share a single space with ergonomic and state-of-the-art computational capabilities.

The Marelli Laboratory has been approved as an extension of the biological and fluids laboratory in the sublevel of Building 1, and capitalizing on unused basement space. This space will accommodate the rapid expansion of the Marelli Laboratory, where researchers will work on structural biopolymers, agriculture, and materials assembly, which are instrumental in the natural and man-made systems of the world. This laboratory will enable work on biotic/abiotic interfaces with environmental impact.

Objective 3: Focus on the future of CEE with accelerated faculty hiring and junior faculty development

Using the momentum of the visiting committee recommendations, the department embarked on aggressive faculty searches over the past two years. There was an unprecedentedly large pool of candidates and, as a result, the department was able to add three new junior faculty members during AY2016. During spring 2016, CEE also extended faculty offers (effective July 1, 2016) to Tal Cohen as assistant professor, and to former University of Pennsylvania professor Ali Jadbabaie in a dual appointment with the MIT Institute for Data, Systems, and Society (IDSS). Details on FY2016 faculty hires are provided below.

Our future success depends in large part on internalizing our new vision across our two research labs (Pierce and Parsons), developing our junior faculty, and attracting top new faculty. The following are associated highlights and accomplishments in these critical areas. Our strategic priorities also include fueling emerging frontiers of innovation and creative design and empowering our students and faculty to lead Institute-wide cross-cutting initiatives. Hiring excellent faculty is arguably the most critical component to supporting these activities.

The faculty search process was changed this past year to focus on several necessary criteria that differ from those of searches conducted in past years:

- Identify the highest-caliber candidates in compelling intellectual frontiers.
- Look for relevance to the vision and domains of CEE, especially those identified as critical needs.
- Build on CEE's strengths in areas where it can lead. Candidates should be dedicated to educating our students in such a way as to equip them to work as scholars and academic leaders, professionals, and entrepreneurs.
- Find candidates who support and are supported by intellectual communities.

New Faculty Hires

Admir Masic, Benedetto Marelli, and Serguei Saavedra all joined the faculty during the 2015–2016 academic year.

Professor Admir Masic joined CEE on September 1, 2015, in the Pierce Laboratory. He previously worked as an independent group leader at the Max Planck Institute of Colloids and Interfaces in Potsdam, Germany. He earned his PhD from the University

of Turin in Italy. His work is experimental, focused on characterization of structural and mechanical properties including aging and degradation over long time scales. He uses an in situ Raman spectroscopy technique and will build an integrated multi-tool instrument. He is also interested in the study of natural materials to devise novel strategies for the synthesis of complex, damage-tolerant composites, as well as in the degradation and preservation of artifacts, including buildings of historical and artistic value, and infrastructure. Professor Masic recently returned from a two-week summer fieldwork program in Italy, ONE-MA3, where he and about a dozen MIT students studied ancient art, archeology, and architecture. The students' fieldwork is a requirement for Professor Masic's new fall class and lab 1.S993 Heritage Science and Technology.

Professor Benedetto (Ben) Marelli joined the department on November 1, 2015, also in the Pierce Laboratory. Previously, he worked at Tufts University as a postdoctoral scholar in the SilkLab. He describes himself as a biomaterialist with a passion for biopolymers. His research group works in the area of structural biopolymers, biomineralization, and self-assembly. By using biofabrication strategies, the group designs bioinspired materials that work at the biotic/abiotic interface to prevent or mitigate environmental impacts. He brings a wealth of experience and a strong focus on engineering and innovation from a multiple-scale perspective, with interests that include the mechanical and optoelectronic properties of natural polymers, biocomposites, additive manufacturing, and emerging technologies.

Professor Serguei Saavedra joined CEE on January 1, 2016, in the Parsons Laboratory. After earning his PhD in engineering science from Oxford University in 2010, he served as a postdoctoral fellow in the United States and Spain, at the Northwestern Institute on Complex Systems and the Doñana Biological Station Integrative Ecology Group, respectively. Professor Saavedra brings expertise in theoretical ecology to the department, introducing a complementary strength to existing research and education.

Faculty Promotions

Colette Heald was promoted to associate professor with tenure effective July 1, 2015. Heald also accepted the position of associate department head effective July 1, 2016, replacing Professor Elfatih Eltahir, who has stepped down from the role. Heald's work in biosphere-atmosphere interactions, aerosol sources and transformations, and the connections between atmospheric chemistry and climate has led to groundbreaking studies that involve observation of the atmosphere from scales including ground stations, aircraft campaigns, and satellite sensors with global models of chemistry and climate. In a recent study, Heald demonstrated how ozone can collude with climate change to curb crop yields and threaten global food security.

Jesse Kroll was also promoted to associate professor with tenure, effective July 1, 2016. In addition, Kroll is the new chair of the CEE Graduate Education Committee (effective June 1, 2016) as Professor Heidi Nepf steps down from that role after several years of service. His research involves the experimental study of the properties and chemical transformation of organic species in the Earth's atmosphere. Particular interests include the development of new analytical tools for the measurement and characterization of organics in both the gas and the condensed phase and the use of these tools in the lab

and field to better constrain the amount, nature, and chemical evolution of atmospheric organics.

Faculty Professorships

On October 10, Provost Martin Schmidt announced that Department Head Buehler had been appointed to the McAfee Professorship of Engineering. Schmidt recognized Buehler's stature and impact in research, and his work in developing and implementing a new vision and strategic plan for CEE.

Otto X. Cordero was selected to receive the 2016–2018 Doherty Professorship in Ocean Utilization for his work on "Systems Ecology of Particle Attached Microbial Communities." The two-year position paves the way for promising nontenured professors to undertake marine-related research that will further innovative uses of the ocean's resources. Cordero, a 2015 addition to the CEE faculty, studies the ecology and evolution of natural microbial collectives.

CEE announced in May that three additional professors received named Institute-wide professorships effective July 1, 2016, in recognition of their important contributions to the department and the Institute. Elfatih Eltahir was selected for the Breene M. Kerr Professorship for a five-year term, Benedetto Marelli was appointed to the Paul M. Cook Career Development Professorship for a three-year term, and Admir Masic was awarded the Esther and Harold E. Edgerton Career Development Professorship for a three-year term.

New Joint Appointments

Caitlin Mueller, assistant professor in the MIT Department of Architecture, was appointed as a joint faculty member in CEE in 2015. Professor Mueller presented at CEE's aforementioned Infrastructure Innovation in a Changing Environment Conference last November, explaining to the audience that architectural design and structural engineering analysis go hand in hand but often are not considered or studied together. Her new academic collaboration with CEE is designed to foster this greater connectivity across disciplines. In fact, she and Professor John Ochsendorf this past April hosted the Creativity in Engineering Symposium, an event open to the entire MIT community that featured leading international structural engineers.

Faculty Retirements

Professors Jerome Connor and Eduardo Kausel retired effective July 2015. Kausel stayed on as a post-tenure professor. A faculty member since 1978 and an MIT alum, Professor Kausel has been instrumental in structural dynamics, mechanics, and numerical modeling as well as a world leader and recognized authority in the field of soil-structure interaction and soil dynamics. In late 2015, Kausel was elected into the Chilean Academy of Engineering, and in April 2016 he published his first biomechanics paper in Stem Cell Reports: "Integrated Analysis of Contractile Kinetics, Force Generation, and Electrical Activity in Single Human Stem Cell-Derived Cardiomyocytes." The paper measures and predicts how strongly cardiomyocytes made from stem cells beat, including the contractile force of each cell. Kausel was responsible for the mechanical model outlined in the paper.

Professor Daniele Veneziano officially retired on September 1, 2015, but he also continued at MIT as a post-tenure professor, advising students and teaching 1.010 Uncertainty in Engineering and 1.151 Probability and Statistics in Engineering.

Faculty Deaths

Frank E. Perkins, professor emeritus of civil and environmental engineering, former CEE department head, and later associate provost and dean for graduate education at MIT, died March 5, 2016, at age 82 following a long struggle with Parkinson's disease. The major portion of Perkins's career was spent at MIT, where he was appointed to the faculty in 1966. His principal research and teaching interests were in the areas of hydraulics, hydrology, and water resource analysis, with a special emphasis on the development of computer models. He also conducted research on water resource development in several South American countries and on issues of dam safety in the United States.

Annual Research Speed Dating Event

CEE held its annual Research Speed Dating event at the MIT Media Lab on February 18, 2016, organized by junior faculty. During this event, faculty members, postdoctoral associates, graduate students, and research associates gave five-minute research presentations. This year, several freshmen who worked on mini-UROP projects also participated for the first time.

Cross-Disciplinary Seed Funding for New Faculty Research

In November 2015, an MIT team and researchers from the Kuwait Institute for Scientific Research and Kuwait University were awarded a $4 million grant for "The Underworlds Project: A Smart Sewage Infrastructure for Kuwait." This study of real-time epidemiology—conducted by Professors Eric Alm, Elfatih Eltahir, and Martin Polz, among others—will combine novel concepts in smart city design and urban informatics with advances in biological engineering and bioinformatics to analyze biomarkers in urban sewage.

In July 2015, J-WAFS awarded $1.8 million in its first round of seed grant funding to MIT researchers. Two CEE faculty members, Heidi Nepf and Dennis McLaughlin, received funding for projects that strive for ways to ensure water and food security. Nepf was selected for her proposal to explore the potential of constructed wetlands, not only as a stormwater solution but more fundamentally as urban resiliency infrastructure. McLaughlin received funding for his proposition to support donors, government agencies, nongovernmental organizations (NGOs), and aid organizations in their efforts to maximize their impact on food security.

Two other new CEE cross-disciplinary research projects began in fall 2015: "Fluid Fragmentation into Droplets Meets Microbiology," submitted by Professors Martin Polz and Lydia Bourouiba, and "From Measurement Data to Environmental Information: Interpreting Air Quality Sensors via Data Mining and Knowledge Discovery," submitted by Professors Marta Gonzalez, Colette Heald, and Jesse Kroll.

In May 2016, J-WAFS announced its second round of seed grants, which included additional funding for CEE professors. Professor Heald was awarded a grant for her project "Air Pollution Impacts on Global Crop Yields," Professor Martin Polz received a grant for "Bacterial Viruses as Pathogen Control Agents in Aquaculture Systems," and Professor Ruben Juanes was awarded funding for "Gravity Fingering during Water Infiltration in Soil: Impact on the Resilience of Crops and Vegetation in Water-stressed Ecosystems."

Objective 4: Show leadership in MIT-wide initiatives by engagement across the Institute, defining a clear positioning of CEE at MIT

Social media, open online courses, crowd sourcing, NGO initiatives, and grassroots movements are empowering new conversations and research to solve complex problems. This greater inclusiveness enhances our education and work, so we embrace it and seek opportunities to leverage its power.

Social Media Outreach and Statistics

The following statistics reflect continued growth in awareness and engagement of CEE online. Note that the statistics do not include any staff or faculty online accounts. For example, Department Head Markus Buehler also has seen significant growth in the number of followers of his professional LinkedIn and Twitter accounts.

Departmental Facebook Page

In June 2015, our Facebook posts reached an average of 402 people (organic, below, is defined as growth without paid advertisements). This increased in 2016 by 83% to an average of 736 people per post. For page "likes," we began with an average of 8,042 in June 2015. This increased by 32% in July 2016 to 10,582 page "likes."

Department of Civil and Enviromental Engineering Facebook Page Statistics, July 1, 2014 through July 13, 2016.

	July 1, 2014	June 25, 2015	July 13, 2016	2015 to 2016 increase
Average organic post reach	193	402	736	83%
Average page "likes"	4,568	8,042	10,582	32%

Departmental Instagram Page

CEE has an additional presence on Instagram, which is known primarily for photos. Although Instagram does not provide analytics, CEE had 128 followers in June 2015. This increased by 330% in 2016 to 550 followers. In 2015 Instagram introduced video uploading, which we have adopted. CEE community members can use #ONEatMIT and tag @MIT_CEE, which we frequently repost. We conducted several Instagram photo contests over the past year that were very well received.

Twitter Activities

In June 2015, @MIT_CEE tweeted an average of 32 times a month. This increased by 28%, to an average of 41 tweets per month (not including retweets), in June 2016. Between September 2014 and June 2015, 1,259 people visited our Twitter page; in June 2016, 2,241 people visited, an increase of 78%. As of June 2015 we had 869 followers, and by June 2016 we had reached 1,571 followers (an 81% increase). Our tweet impressions (people who click and engage) averaged 21,200 from September 2014 to June 2015. This rose by 107% to 43,900 in June 2016. From September 2014 to June 2015, we had an average of 37 "mentions" (other tweets that tag #MITCEE); as of June 2016, we were mentioned an average of 50 times.

Department of Civil and Enviromental Engineering Twitter Activity Statistics, September 2014 through June 2016.

	September 2014–June 2015	June 2015–June 2016	Increase
Average tweets	32	41	28%
Average profile visits	1,259	2,241	78%
Number of followers at end of term	869	1,571	81%
Impressions	21,200	43,900	107%
Mentions	37	50	35%

LinkedIn Page

As of June 2015, the CEE LinkedIn page had attracted 135 followers. In June 2016, our number of followers increased to 476 (a 253% increase). Unfortunately, in April 2016, LinkedIn announced that it will discontinue many of its features on higher education pages, including university rankings, which will make it more difficult to view detailed analytics for higher education pages.

Objective 5: Enhance alumni engagement and resource development

On May 11, Department Head Buehler was the guest speaker at Building a Resilient World through Big Engineering, the MIT Club of Northern New Jersey's annual dinner event. Professor Buehler also had an opportunity to network with the attendees and encouraged them to reach out to him for ideas for collaboration with the department.

CEE Resource Development hosted the New Research Alumni Breakfast (as noted above), which attracted approximately 70 alumni to campus. In the spring, CEE again hosted an alumni breakfast as well as Pierce Laboratory tours to coincide with the extended MIT Commencement weekend.

CEE continues its seasonal ONE@MIT e-newsletter for alumni. Analytics show that open rates for the newsletter exceed the average education industry standards.

Development and Fundraising

The department continued to expand its effort to increase philanthropic support for CEE. Department fundraising efforts helped support our goal of providing faculty and students with innovative education and research programs to develop real-world applications that have a large-scale impact on people and sustainability.

Paul Hohenberger, CEE development officer, continued to lead resource development efforts with alumni, CEE friends, and the central MIT Resource Development Office.

Department Head Markus Buehler continued to expand his philanthropic outreach by hosting a significant number of business, government, and alumni delegations from around the globe to discuss the department's vision and research initiatives. He and Hohenberger also traveled frequently on gift prospect trips to New York City and Washington, DC.

The department received a number of significant new gifts and pledges in FY2016 to support its important initiatives. For example, the department received a pair of seven-figure gifts, one that provided new funding to support an endowed fellowship and another to be used at the discretion of the CEE department head for building projects and faculty support.

Accomplishments

Faculty Activities and Initiatives

In September 2015, MIT and the Office Chérifien des Phosphates (OCP) Group of Morocco made official their joint collaboration on a new program that involves an opportunity for MIT engagement in the development of the School of Engineering at the King Mohammed VI Polytechnic University. Professor Elfatih Eltahir will serve as the program director for this CEE-housed initiative. The King Mohammed VI Polytechnic University, launched in 2009 by King Mohammed VI under OCP's large-scale strategic project and located between Casablanca and Marrakesh, will emphasize research and development in areas critical to the economic, social, and environmental future of Morocco. Funding support is $5.25 million over five years.

On October 7, MIT announced a pilot initiative in its Supply Chain Management (SCM) program. Students who excel in a semester's worth of graduate classes online and also pass a comprehensive proctored exam can earn an MITx MicroMaster's credential. They can then apply to the full SCM master's program and receive course credit for the work they did online, as well as come to MIT to complete the program and earn a master's degree after a semester on campus. Professor Yossi Sheffi, director of the MIT Center for Transportation and Logistics, will lead the creation of course content and the nurturing of program students.

The larger a company's operations, the more susceptible it becomes to disruptions such as natural disasters, political upheaval, industrial actions, and climate change. In his new book *The Power of Resilience: How the Best Companies Manage the Unexpected*, Professor Yossi Sheffi discusses how large firms can lessen the shocks of a volatile world and essentially implement effective disruption-prone operations.

With significant changes in the publishing landscape, open discussions on finding the right outlet to publish scientific work are critical to better connect students, postdocs, and faculty with scientists and publishers. On November 30, the department hosted a Getting Published panel for the entire MIT community that covered aspects of open access publishing, innovative models of peer review and publishing, and related topics. "Practically all the editors put the importance of good writing at the top of their recommendations," said Professor Martin Polz, who served as the panel moderator.

On December 13, a group of MIT professors, including Professor Elfatih Eltahir, penned an opinion letter to the *Boston Globe* asserting that climate scientists understand much more about climate change than many realize. The letter was in response to a prior piece submitted by Freeman Dyson, professor emeritus at the Institute for Advanced Study at Princeton University, claiming that misunderstandings about climate change marred the recent Paris climate discussion. "[We are] dismayed by the limited understanding and short-sighted interpretation of basic elements of climate science exhibited in [this piece]," they wrote. "Like Dyson, we too are environmentalists concerned with many problems, including global warming. None of them should be ignored."

Professor Penny Chisholm was featured in the January/February 2016 edition of the *MIT Technology Review* for her work on understanding complex marine ecosystems and how they will respond to global warming. Chisholm, an ecologist and marine biologist, is widely recognized for her discovery of *Prochlorococcus*, a type of ocean-dwelling bacterium that produces up to 10% of all oxygen generated by photosynthesis on Earth each year. *Tech Review* quotes her work as "critical to understanding the complexity of marine life and predicting how climate change might ultimately perturb it."

Department Head Markus Buehler and Professor Pedro Reis were elected to the Society of Engineering Science's Board of Directors effective January 1, 2016. The organization's membership boasts leading engineers, scientists, and mathematicians from around the world who focus on opportunities at the interface of engineering, sciences, and mathematics.

Effective January 2016, Department Head Buehler was named editor in chief of the *Journal of the Mechanical Behavior of Biomedical Materials*. With a primary focus on the synthesis of materials science, biology, and medical and dental science, this publication specifically concerns itself with the mechanical deformation—damage and failure under applied forces, tribology, fatigue, creep, wear, and adhesion—of biological material and biomaterials, including those designed to mimic or replace biological materials.

Professor Eltahir has long been interested in the *Aedes aegypti* mosquito, which is responsible for the devastating dengue virus and now Zika. In a Q&A with the MIT School of Engineering, Eltahir explained how his work simulating regional climate processes to understand land surface hydrology can also serve to explain the Zika virus outbreak and suggest potential mitigation and prevention approaches.

On March 4, Department Head Markus Buehler's work was reviewed in a piece by the *New York Times* titled "At MIT, Science Embraces a New Chaos Theory: Art." The

article covered several artistic collaborations within the Institute, including Buehler's continued work with artist Tomás Saraceno on the study of the structure of spider silk protein and its potential as a future, synthetically replicated building material. "Tomás and I have pushed the boundaries in what we thought we could do," Buehler said. "[As scientists] we ground ourselves when we actually get to work, but it's important to be creative. That's why I put Tomás and the students in the same room. They can learn from him as an artist to think wildly, and that's necessary to solve a problem."

Senior Lecturer Fred Salvucci was interviewed by NPR *Here and Now* host Jeremy Hobson on April 13. The feature ("Public Transportation In America: How It Stalled And Where It's Going") describes how the money Massachusetts received 50 years ago for new commuter rail and rapid transit equipment, as well as track and infrastructure renovation and expansion, came from funding awarded to the commonwealth in lieu of interstate highway funds that were not accepted by the state.

Professor John Ochsendorf was appointed chair of the Centennial Steering Committee and co-chair of MIT's Frontiers of the Future Colloquium, which featured Professor Lydia Bourouiba as one of only 13 MIT faculty selected to present. As part of MIT's Century in Cambridge celebration, the Institute hosted "Moving Day at MIT" on May 7, including a "Crossing the Charles" competition meant to recapture the spirit of the Institute's momentous move in 1916 from Boston to Cambridge.

Professor Benedetto Marelli reported a study in which he and coworkers added a thin silk coating to strawberries, resulting in increased fruit firmness and prevention of decay. The coating, which is 27–35 microns thick, is thin and odorless and does not affect the fruit's texture. Since his arrival at MIT, Professor Marelli has expanded his research in this area and included CEE students in the experimentation.

Professor John Ochsendorf and CEE alumnus and Cambridge University senior lecturer Matthew DeJong SM '05, PhD '09, were among the participants at the May opening of the Venice Architecture Biennale, which displays work from architects and designers addressing major challenges and issues facing humanity around the globe. Ochsendorf and DeJong are involved in a pair of projects that demonstrate the structural, economic, and environmental benefits of compression vaults. The biennale extends through November 27.

Student Outreach

On February 5, the CEE Outings Committee organized an evening of ice skating, music, and hot chocolate at MIT's Johnson Ice Rink, attended by more than 90 students. Graduate student Jane Chui as well undergraduate students Emily Shorin and Gillian Grogran offered skating lessons to over 50 of the attendees.

The theme of the third annual Course 1 Video Competition was "How does YOUR Course 1 science and engineering research reflect Big Engineering?" The showcase, held on March 11, featured 10 two-minute films that answered the call. Junior Kali Rosendo took first place for a video highlighting her TREX experiences over the past year. A team of graduate students—Wenjia Wang, Ruby Fu, Brittany Huhmann, William Porter, Xuanzong

Guo, and Judy Yang—claimed second prize with a video on arsenic in groundwater. Transportation students Patton Doyle, Katie McLaughlin, Martin Elliot, Maya Shopova, and Dan Glick-Unterman left with third place for their video on the Detroit Community Rail. Graduate student Justin Chen was the audience favorite for his video on small motions and structural health monitoring. All of the videos are available on the CEE YouTube channel, including a video produced by headquarters with mascot Gunner.

During the spring 2016 Campus Preview Weekend CEE hosted a beverage serving station, Café at ONE, manned by administrative officer Angela Mickunas and the APO staff. The beverage station provided a refreshing respite for undeclared freshmen touring the many department exhibits.

The Grilled Cheese Sandwich Dinner, with Department Head Markus Buehler and Professors Elfatih Eltahir, Benedetto Marelli, and Admir Masic serving as "executive chefs," offered CEE students a break during study week for fall and spring final exams.

In addition, continuing an established tradition for graduate and undergraduate students to meet with Department Head Buehler in a more casual setting, multiple coffee breaks and refreshment get-togethers were held in both the fall and spring semesters.

A new summer-themed photo contest using the Twitter hashtag #CEEsummer and Instagram is under way for summer 2016, inviting students (along with faculty and staff) to submit photos showing their summer activities that reflect CEE's vision.

CEE CC Mei Distinguished Speaker Series

Professor Lydia Bourouiba expanded her CC Mei Distinguished Speaker Series to include more speakers, further raising visibility for CEE and its vision beyond MIT audiences. Topics and speakers included:

- "From Individual Behavior to Collective Dynamics: Modeling and Control of Congestions Waves in Highway Networks" by Professor Michael Zhang of the University of California, Davis
- "Mechanics as an Enabling Tool in Bioinspired Materials and Biological Interactions of Nanomaterials" by Professor Huajian Gao of Brown University
- "Swimming and Crawling in a Turbulent World" by Professor Mimi Koehl of the University of California, Berkeley
- "Non-Newtonian Fluids and the Mathematics of Surfactant Fluids" by Professor Pamela Cook of the University of Delaware
- "Reflections on Emerging Microbial Threats" by Professor James M. Hughes of the Emory University School of Medicine and Rollins School of Public Health
- "The Complex 3D Hierarchical Organization of Bone: Surprising Structure-Function Relations" by Professor Steve Weiner of the Weizmann Institute of Science

Research Highlights

The department's research is diverse and crosses many disciplines. CEE proposal submissions almost doubled from the previous year, from 58 to 101. Research volume remained flat, which was expected due to retirements, Professor Roman Stocker's return to Europe, and new junior hires just coming on board.

Professor Serguei Saavedra, working with a team of European ecology researchers, highlighted some of the major processes shaping the delicate biodiversity of Poland's Bialoweiza Forest in a paper published in *Ecology*, "Seasonal Species Interactions Minimize the Impact of Species Turnover on the Likelihood of Community Persistence." The Bialoweiza Forest is one of the last and largest remaining parts of the immense primeval forest that once stretched across the European Plain. According to Saavedra, the group's results show for the first time how seasonal interaction changes can be related to the long-term persistence of ecological communities.

A team of researchers including Professor Franz-Josef Ulm, postdoc Colin Bousige, and research scientist Roland J.M. Pellenq described the internal structure of kerogen down to the atomic level, in a study published in the journal *Nature Materials*. The findings reveal important details about how gas and oil move through pores in formations deep underground, making it possible to estimate amounts of recoverable reserves more accurately and potentially pointing to better ways of extracting them.

Researchers in Professor Pedro Reis's lab, in collaboration with a team from EPFL in Switzerland, have developed a rapid fabrication technique and a theory that accurately predicts the final thickness of a shell of a known material given the original rheological properties of the material and the geometry of the mold used for the coating. Inspired by the making of chocolate confections such as hollow chocolate eggs and bonbons, the fabrication technique and theory may lead to application innovations for artificial vesicles, smart skins, and protective and packaging films on curved components.

Professor Lydia Bourouiba and her team's work on mathematical modeling and novel experimental investigations of infectious disease transmission appeared as a *Nature* news feature. The feature discussed the novel methods and fundamental fluid dynamics modeling insights used by Professor Bourouiba to understand the process of transmission, particularly focusing on respiratory disease transmission. Various members of the medical community, including the former director of the National Center for Infectious Diseases at the United States Centers for Disease Control and Prevention, commented on the work's importance for filling in key gaps in our current understanding of respiratory pathogens and transmission.

The formulas scientists use to describe traditional fluid flow indicate that puddle water should spread endlessly. However, as most know, this is not the case. Now a team of CEE researchers has solved the mystery of why puddles settle at a given point, publishing their findings in *Physical Review Letters*. "You start with something very simple, like the spread of a puddle, but you get at something very fundamental about intermolecular forces," said Ruben Juanes, CEE professor and senior author of the study led by graduate student Amir Pahlavan and CEE research associate Luis Cueto-

Felgueroso '06. "The same process, the same physics, will be at play in many complex flows." Comprehension of the mechanics of this phenomenon is vital to enhance processes ranging from the lubrication of machinery to the potential sequestration of carbon dioxide emissions in porous underground formations.

Using a mathematical approach, a CEE team developed a domain-specific programming language for generating custom materials based on design specifications. The software, dubbed Matriarch ("Materials Architecture"), allows users to combine and rearrange material building blocks in almost any conceivable shape. "Matriarch could very well be the core of a new molecular design process where engineering decisions can be made at arbitrary scales," according to CEE postdoctoral associate Tristan Giesa '15, coauthor of the study. The open source program will allow engineers to discover new materials and custom design them.

In January, a team of scientists led by Professor Pedro Reis developed a theory to predict how much light is transmitted through a given material and the transparency of a polymer structure as it stretches and inflates. The researchers' newfound understanding of polymer structure may be useful in the design of cheaper materials for smart windows. "For buildings and windows that automatically react to light, you don't have to spend as much on heating and air conditioning," said Francisco López Jiménez, a CEE postdoc in Professor Reis's lab. "The problem is, these materials are too expensive to produce for every window in a building. Our idea was to look for a simpler and cheaper way to let through more or less light by stretching a very simple material: a transparent polymer that is readily available."

The remarkable flexibility of elastin, a crucial building block in our bodies, has remained an unsolved question—until now. In a new analysis of this protein-based tissue published in *Science Advances*, a team including doctoral student Anna Tarakanova SM '15 and Department Head Markus Buehler revealed the details of a hierarchical structure of scissor-shaped molecules that give elastin its properties.

Department Head Buehler and a team of researchers were featured in *Nature Reviews Materials* for their comparative analysis of the composition, structure, and mechanics of a set of representative biological interfaces in nacre, bone, and wood. The team revealed how these interfaces might incite the development of advanced bioinspired composites as a result of their unusual mechanical characteristics.

In collaboration with colleagues from the Polytechnic University of Milan in Italy, MIT engineers are achieving functional diversity in materials by combining a few pure components as building blocks to create diverse structures. The researchers selected bone to investigate these multifunctional composite design principles. The team used pure polymers and 3D printing to create new synthetic materials with a wide range of properties and applications. The research is described in a paper ("Bone-Inspired Materials by Design: Toughness Amplification Observed Using 3D Printing and Testing") published in *Advanced Engineering Materials* by lead author Flavia Libonati, a CEE research affiliate and an assistant professor at the Polytechnic University of Milan.

MIT and Tufts researchers revealed key nano building blocks of natural silk to produce new naturally based membrane filters that are more effective, less expensive, and greener than traditional products. This discovery could lead to new production methods and supply chain economics for water treatment facilities, food manufacturers, and life sciences organizations. The CEE researchers in the group included graduate student Kai Jin, postdoctoral associate Shengjie Ling, and Department Head Buehler. Professor David L. Kaplan contributed from Tufts University. A paper describing the research was published in *Nano Letters*.

Finding the perfect mixture of toughness and ease of fabrication for synthetic hydrogels has been elusive. In a paper published in *Advanced Materials*, Professor Xuanhe Zhao described the world's first robust hydrogel system, tougher than articular cartilage yet capable of encapsulating cells with high viability and being printed into various functional 3D structures. Although 3D printers have already been used to print hydrogels, those gels have not been ideal, according to Zhao. While progress has been made in designing raw materials that have such tough characteristics, crafting them into usable and functional microstructures has proven a challenge. Further tests and tweaks may be needed to see if this tough gel can also play host to actual tissue engineering in a dynamic environment.

A team of CEE professors and graduate students led by Professor Oral Buyukozturk are redesigning the most commonly used human-made material in the world: concrete. Specifically, the researchers are focusing on replacing cement paste with a sustainable and longer-lasting alternative. "If we can replace cement, partially or totally, with some other materials that may be readily and amply available in nature, we can meet our objectives for sustainability," said Buyukozturk. The research involved investigating biological materials and combining knowledge gathered from existing cement paste design tools to create a general bioinspired framework for engineers to design cement "from the bottom up." The research group included Steven Palkovic, lead author and graduate student; Dieter Brommer, graduate student; Kunal Kupwade-Patil, research scientist; and faculty members Masic and Buehler.

Professor Franz-Josef Ulm, Senior Research Scientist Roland Pellenq, and MIT Energy Initiative postdoctoral fellow Katerina Ioannidou aim to make concrete more sustainable, stronger, durable, and climate friendly. Recently, the research team identified the nanoscale forces that control how particles pack together during the formation of cement "paste," and the group wants to control those forces to improve the paste while reducing harmful production impacts on the environment.

Professor Moshe Ben-Akiva and a team made up of both MIT professors and students in the Department of Urban Studies and Planning partnered with the Massachusetts Bay Transportation Authority (MBTA) to create "QualiT," an application of the Future Mobility Sensing (FMS) app developed by researchers from the MIT Intelligent Transportation Systems Lab and the Singapore-MIT Alliance for Research and Technology (SMART). QualiT allows Silver Line passengers to rate their trips and MBTA experience. QualiT takes location data and anonymous feedback to measure passenger satisfaction, with the goal of helping MBTA improve its services.

On June 14, MIT announced the launch of Access MIT, a new series of commuter benefits for MIT faculty and staff. Benefits include free unlimited subway and local bus usage, increased subsidies for parking at MBTA stations and commuter rail tickets, and a shift to pay-per-day parking at many lots on campus. The Access MIT program stemmed from initial research conducted by the Transit Lab and CEE research associate John Attanucci. According to Attanucci, "With this new approach, commuters will be able to drive one day then ride the T the next. By having options, we can begin changing the way people think about commuting."

New research shows how to identify buildings where retrofitting for energy efficiency will have the biggest impact on a city's overall greenhouse gas emissions. The project, which requires only minimal information about the buildings and their energy use, was developed by Professors Marta González and Franz-Josef Ulm along with their colleagues. The results will be reported in the journal *Interface*.

The US Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E) announced that MIT researchers, along with colleagues from the University of Massachusetts, received a grant to design and test an innovative system that provides incentives for people to make energy-conscious travel decisions. CEE professor Moshe Ben-Akiva will co-lead the project, which will develop a method that uses real and simulated personal travel data to reward people to shift their routes, departure times, modes of travel, and vehicles based on live information.

A study of high-resolution climate models by Professor Elfatih Eltahir and alumnus Jeremy Pal '97 revealed that parts of the Persian Gulf region could be hit with unprecedented events of deadly heat as a result of climate change. The study, published in the journal *Nature Climate Change*, concluded that the Persian Gulf's shallow water and intense exposure to sunlight make it a regional hotspot where climate change, in the absence of significant mitigation, is likely to impact human habitability. Eltahir said that this threshold "has, as far as we know…never been reported for any location on Earth."

A team of MIT researchers, including Professors Otto X. Cordero and Martin Polz and postdoctoral associate Manoshi S. Datta, conducted a study showing how bacteria from the ocean assemble into multispecies communities around particles of organic matter and how these communities could shape particle degradation and impact oceanic carbon cycles. "Our results suggest that the existing ecological theory developed for plant communities that extend over scales of kilometers, may be applicable to microbial communities congregated on particles of tens of microns in size," said Cordero, the lead senior author on the study.

A CEE team investigated the impacts of large-scale cropland irrigation on rainfall patterns in the East African Sahel around the Gezira Irrigation Scheme. The researchers—Professor Eltahir, research affiliate Ross Alter, and Eun-Soon Im of SMART—combined theoretical modeling analyses with observational evidence gathered since 1930. According to Eltahir, "Large-scale development of irrigation systems is a good example of human activity that has changed land cover and the environment significantly in many regions of the world. In all development projects, we need to

better understand the potential impacts of our actions on the environment before we mindlessly develop."

Through a study explaining how rain droplets attract aerosols out of the atmosphere, a group of atmospheric chemists at MIT have determined the extent to which rain is effective in cleaning the atmosphere. Professor Dan Cziczo, who has a joint appointment in CEE and the Department of Earth, Atmospheric, and Planetary Sciences, led the study, in which he and his team calculated rain's coagulation efficiency: the ability of a droplet to attract particles as it falls. They found that the smaller the droplet, the more likely it was to attract a particle. "Say you're a modeler and want to figure out how a cloud in Boston cleans the atmosphere versus one over Chicago that's much higher in altitude—we want you to be able to do that, with this coagulation efficiency number we produce," Cziczo said. "This can help address issues such as air quality and human health, as well as the effect of clouds on climate."

Awards and Recognition

Faculty Awards and Recognition

The faculty in CEE have received numerous significant awards, reflecting their excellence and impact within the Institute and beyond.

Professor Harry Hemond and coauthor Liz Fechner were presented the 2015 Texty Textbook Excellence Award in the Physical Sciences category for the third edition of their recent book, *Chemical Fate and Transport in the Environment* (Elsevier/Academic Press).

Professor Jesse Kroll was recognized for his work in the sector of geosciences in Thomson Reuters's "The World's Most Influential Scientific Minds." This annual compilation consists of elite authors who have been prolific in the production of highly cited papers. The list covers an 11-year period and features over 3,000 scientists who have won acclaim and approval from their peers.

Research scientist Zhao Qin and Department Head Markus Buehler received a Most Cited Paper Award for their coauthored paper "Robustness-Strength Performance of Hierarchical Alpha-Helical Protein Filaments," published in the *International Journal of Applied Mechanics*. It was selected by the editor in chief, among all papers published between 2009 and 2015, as the journal's inaugural award winner.

At the 2016 Women's Transportation Seminar (WTS) international spring gala, senior lecturer Fred Salvucci was recognized for his significant contributions to the transportation industry and his support of women and minorities in the field with the Honorable Ray LaHood Award (Man of the Year), a new honor created this year. In addition to being recognized at an international level, Salvucci was honored at the WTS Boston Chapter's annual awards and scholarship dinner on June 29.

The Transportation Research Board Executive Committee selected Professor Moshe Ben-Akiva and his team's paper as the 2015 winner of the Pyke Johnson Award. The MIT

Intelligent Transportation Systems Lab at SMART developed an innovative smartphone-based automated travel survey system called Future Mobility Sensing (FMS). The paper, presenting data collected during 2012–2013 field testing of FMS in Singapore, demonstrated the system's capability to collect information delivering a previously unobtainable range of behavioral insights.

Professor Dara Entekhabi was selected by the American Geophysical Union to receive the 2015 Hydrologic Sciences Award. Entekhabi is widely regarded as a leader in the exploration of the intricate processes that occur at the land-atmosphere boundary. His research focuses on the disciplines of hydrology, meteorology, and Earth remote sensing, with a specialized interest in the interactions between the land and atmosphere as well as their role in hydrology and meteorology.

Department Head Markus Buehler was selected as the 2016 recipient of the Outstanding Young Scientist Award by the NANOSMAT Society an international organization focused on materials related to nanoscience, engineering, and nanotechnology. This award recognizes professional career achievements among those up to 45 years old. Specifically, Buehler was selected for his significant contributions in making nanotechnology sustainable and scalable for large-volume materials applications and for his development and application of new modeling, design and manufacturing approaches for advanced materials. Earlier this year, Buehler was also elected a fellow of the NANOSMAT Society. In addition, Buehler received the 2015 Foresight Institute Feynman Prize in Theory for his work in molecular nanotechnology. He was acknowledged for his research enabling new multiscale models in hierarchical systems.

Professor Otto X. Cordero received a 2016 Simons Early Career Investigator in Marine Microbial Ecology and Evolution Award from the Simons Foundation for his project "Systems Ecology of Particle-Attached Microbial Communities in the Ocean." These awards help launch the careers of outstanding investigators who use quantitative approaches to advance our understanding of marine microbial ecology and evolution. Professor Cordero also was selected as one of 11 MIT recipients of the 2016 Sloan Research Fellowship, a $50,000 fellowship given to early-career scientists and scholars whose achievements and potential identify them as rising stars among the next generation of scientific leaders. As noted above, Cordero studies the ecology and evolution of natural microbial collectives, with a particular focus on understanding how social and ecological interactions at a small scale impact the various global dynamics of microbial ecosystems.

Professor John Ochsendorf won the 2016 Gordon Y. Billard Award, given annually at the MIT Awards Convocation in May for "special service of outstanding merit performed for the Institute." Among his many achievements, Ochsendorf was cited for his leadership of the MIT 2016 Centennial celebration events.

Professor Masic received the WITec 2016 Gold Paper Award for his microscopic analysis of the teeth of the red sea urchin. Masic and two other scientists used confocal Raman microscopy and energy-dispersive X-ray spectroscopy to analyze the molecular and elemental composition of the teeth.

Professor Carolina Osorio was invited to speak at the upcoming National Academy of Engineering Frontiers of Engineering symposium in Finland. She is one of two engineers from the United States invited to discuss the road to future urban mobility.

Professor Saurabh Amin received a National Science Foundation CAREER Award for his project titled "Resilient Design of Networked Infrastructure Systems: Models, Validation, and Synthesis." The goal of the project is to develop a practical design toolkit and platform that will enable the integration of resiliency-improving control tools and incentive schemes for cyber-physical systems deployed in civil infrastructures. In addition, Professor Amin won a Google Faculty Research Award for his proposal "Estimating Social Welfare of Traffic Information Systems. That award will permit Amin to collaborate for a year with Google experts in transportation information systems.

At the 2015 Materials Research Society fall meeting, Professor Xuanhe Zhao was named the recipient of the Extreme Mechanics Letters Young Investigator Award for a paper titled "Predicting Fracture Energies and Crack-Tip Fields of Soft Tough Materials." Zhao's paper described a quantitative model that reveals the toughening mechanism of soft materials such as hydrogels and provides a rational foundation for the design of future soft tough materials.

Student Awards and Recognition

Omar Swei, a PhD candidate expected to graduate in February 2017, is the recipient of a 2016 Fulbright grant. Swei is one of eight MIT students and graduates to receive the prestigious grant. Swei will reside in Jordan and design new software to help transportation planners improve maintenance on the state-owned highway system.

Graduate student Joanna Moody was selected by the Board of Regents of the Eno Center for Transportation to participate in the 24th annual Eno Future Leaders Development Conference in Washington, DC, in June. Each year, this conference offers 20 of the nation's top graduate students in transportation a first-hand look at how national transportation policies are developed. Additionally, Moody had the opportunity to meet with government officials, leaders of associations, and members of Congress and their staffs to see how the nation's transportation policies are debated, shaped, formed, and ultimately adopted and applied.

In May, Stephanie Chin received an Institute-wide Freshman Award for Distinguished Achievement in Research for her UROP work on the use of nano cement additives, conducted under the supervision of Professor Oral Buyukozturk and Dr. Kunal Kupwade-Patil. As part of her UROP work, Chin traveled with Buyukozturk's group to Kuwait in January and presented results of her in situ experiments using nano additives to characterize the cement matrix and structure at various length scales.

Also in May, Zhao Ma, a dual-degree candidate (MEng and MArch), won the Marvin E. Goody Award for his thesis proposal, "Drone-based Assembly System for Generative Design and High-tolerance Construction." This award is given to a graduate student who is expecting to complete his or her master's thesis at the end of the following term and who explores the bond between good design and good building, extends

the horizons of existing building techniques and materials, and fosters links between academia and the building industry.

CEE graduate student Mark Membreño made it to the final rounds of the 2016 MIT IDEAS Global Challenge Innovation Showcase for his Bolivia GSAP (Global Sustainable Aid Project) toilet idea. Although he did not win the competition, his idea supports innovation and entrepreneurship as a positive public service, the mission of the annual challenge.

Graduate student Rebecca Heywood SB ’12, SM ’16, and graduating senior Samantha Harper ’16 received individual awards at the 2016 MIT Awards Convocation in May. Heywood was presented the John S.W. Kellett (1947) Award, which recognizes an MIT individual or group for commitment to creating a more inclusive environment at MIT, including but not limited to improving the experience for lesbian, gay, bisexual, transgender, and questioning individuals. Harper won the Laya and Jerome B. Wiesner Student Art Award, presented annually for outstanding achievements in and contributions to the arts at MIT. Harper started a new theater group on campus to give students the opportunity to express themselves in a new way.

The 2016 Shoji Prize for Innovation in IT in Civil Engineering was presented to doctoral student Kai Pan for his accomplishments in the development and application of a smooth article hydrodynamic code to the area of rogue wave impacts on offshore structures. Dr. Shoji, a supporter of CEE research since 1991, was a visiting professor in the department in 2006 and has spent several months doing research on information technology automation in the construction industry. He began sponsoring his eponymous prize in 2011.

Two CEE graduate students won Council of University Transportation Centers awards. Samuel Levy ’15 and Maite Pena Alcaraz, both students of Professor Joseph Sussman, were selected to receive the 2015 Charley V. Wootan Memorial Award for the best thesis in policy and planning. Levy won in the master’s category for his MST thesis, “Capacity Challenges on the California High-Speed Rail Shared Corridors: How Local Decisions Have Statewide Impacts.” Alcaraz won in the PhD category for “Analysis of Capacity Pricing and Allocation Mechanisms in Shared Railway Systems.”

In November, Earth Science Information Partners (ESIP) announced its 2016 class of student fellows, including Sam Silva, a graduate student in Professor Colette Heald’s group focusing on atmospheric chemistry and physics. The ESIP fellowship provides Earth and computer science graduate students and postdoctoral researchers the opportunity to bridge the gap between informatics and Earth science, as well as work closely with professionals in ESIP’s interdisciplinary, cross-sector groups on current Earth science problems.

Course 1 graduate student Jennifer Apell was selected as one of the 2015 winners of the American Chemical Society’s C. Ellen Gonter Environmental Chemistry Award, which is presented to graduate students at US and international universities who submit the highest-quality research papers. Apell secured the award for her work deploying passive samplers in situ in the sediment bed of a contaminated lake in Natick, MA.

Grace Xiang Gu, a mechanical engineering graduate student who works in collaboration with Department Head Markus Buehler in MIT's Laboratory for Atomistic and Molecular Mechanics, won the 2015 Best Poster Award at the University of Illinois bionanotechnology summer institute. The program consisted of two weeks of lectures and hands-on training in engineering and physical science laboratory techniques by experts in the field. Gu's poster displayed her work on bioinspired composite designs from optimization and 3D printing.

Working in collaboration with Department Head Buehler and lab members GangSeob Jung, Zhao Qin '13, and Francisco Martin Martinez, high school student Kristine Zhang from Saratoga, CA, achieved a spot in the final top 10 for her research presentation at the 2015 summer Research Science Institute (RSI). She was selected to give an encore presentation of her work to all RSI students, staff, and board members, as well as MIT and Harvard faculty. Zhang's work focused on using molecular dynamics simulations to understand the mechanical properties of a novel semiconductor, monolayer molybdenum disulfide, for the prevention of material failure in new electronic devices. The RSI, sponsored by the Center for Excellence in Education and hosted by MIT, is a highly competitive summer research program for rising high school seniors around the world.

Staff Awards and Recognition

Parsons Laboratory administrative assistant James (Jim) Long was presented an Infinite Mile Award at the School of Engineering's 16th annual awards ceremony on May 25. The Infinite Mile Awards recognize staff members who surpass expectations in three categories: excellence, diversity and community, and institutional cooperation. Long was cited in the excellence category, which recognizes staff members who stand out "because of their high level of commitment and because of the enormous energy and enthusiasm they bring to their work."

2016 Annual Departmental Awards: Faculty, Staff, and Students

These awards celebrate all that is CEE. This past year the department added several new awards to stimulate the local community to identify and further the excellence within the department.

The CEE Leadership and Community Award this year went to senior Amanda Parry '16. This award recognizes an undergraduate student, at any level, who has made exemplary contributions to improve the CEE community, fostered excellence and diversity, and contributed to a culture of inclusiveness. Among her many accomplishments, Parry has been a leader on the executive board of the CEE Student Association for the past three years and served as its president during this past academic year.

Also, as noted above, Parry received one of two Senior Capstone Class Awards for her research on bridge abutments. Olivia Massey '16 received the second capstone prize for her research on sustainable ways to feed the global population.

The Leo (Class of 1924) and Mary Grossman Award was presented to senior Daniel Mascoop '16 in honor of Mr. Grossman, who had a professional career in highway

design and planning. The Grossman Award is given to an undergraduate student with a strong interest in transportation and a strong academic record. Mascoop is very active in research in the transportation fields, working on an internship with Professor Moshe Ben-Akiva in Singapore and with Professor Joseph Sussman on his senior capstone project. Mascoop was also one of the leaders in the fossil fuel divestment movement at MIT over the past year.

Two senior undergraduates, Josefin Betsholtz '16 and Emily Shorin '16, received the Paul L. Busch (1958) Prize, which goes to undergraduates in environmental science and engineering for academic achievement and contributions to the CEE community in honor of the late alumnus. Shorin is a member of the Tau Beta Pi Engineering Honor Society and is actively engaged in environment, energy, and policy issues. Betsholtz's research focus is on crop yield variability in sub-Saharan Africa and finding innovative solutions to help feed the world's growing population.

Juan Hermosilla '57 visited the campus from his native Guatemala this spring to celebrate MIT's centenary celebration of its move from Boston to Cambridge. Unfortunately, he had to return home before congratulating the student who received his eponymous award, the Juan Hermosilla Prize. The prize recognizes an undergraduate's exceptional talents in mechanics, materials, structures, and design. This year the award went to Paul Twijukye '18 of Uganda. Twijukye's name will be added to the Hermosilla Prize plaque mounted in the CEE student lounge in Building 1.

The Tucker-Voss Award was established in memory of Professor Ross F. Tucker and Professor Walter C. Voss, who were the first two heads of the Department of Building Construction, Course 17. In the 1950s, Course 17 merged with the Department of Civil Engineering and the first Tucker-Voss Award was presented. This award is given annually to an undergraduate or graduate student who shows particular promise in the field of building. The 2016 recipient was graduate student Dimitrios Pagonakis '15, MEng '16. Pagonakis's unique background in mathematics and structural mechanics enables him to address novel problems, the solutions to which have the potential to significantly advance the field of building construction.

The Trond Kaalstad (Class of 1957) Fellowship was awarded to graduate student Joanna Moody SM '16. This award, named after a former CEE administrative officer, recognizes outstanding graduate students who display leadership or contribute significantly to the well-being of the CEE community. Moody's service to CEE includes acting as coordinator of the MIT Transportation Showcase, the Center for Transportation and Logistics Global Leadership Lecture Series, and the MIT-TDC (Transportation Diversity Council) Summit in New York. She also has been an active board member of both the MIT Transportation Club and the Transportation Student Group.

The Maseeh Award for Excellence as a Teaching Assistant went to Scott Middleton for his significant contributions to course work and student support. The award is made possible by the generosity of Fariborz Maseeh ScD '90.

Alexandra Konings won the CEE Best Doctoral Thesis Award for "Microwave Remote Sensing of Water in the Soil-Plant System."

The CEE Postdoctoral Scholar Award went this year to not one, but two, deserving recipients. Konrad Krakowiak and Marie-Julie Dalbe were both recognized for their excellence in postdoctoral scholar mentoring, teaching, and excellence.

Faculty awards went to Professor Colette Heald and Professor Elfatih Eltahir. Eltahir received the Distinguished Service and Leadership Award for his exceptional contributions to academic and research programs. The Maseeh Excellence in Teaching Award was presented to Heald for her outstanding teaching skills and dedication in undergraduate and graduate subjects, including her educational contributions in the atmospheric chemistry program, her work leading undergraduates in the senior capstone class, and her extensive experience mentoring students in TREX.

The CEE Excellence Award for Staff recognizes a CEE staff member for excellent contributions to the community, including commitment to professionalism, dedication, and best practices, as well as fostering a culture of diversity, inclusiveness, and innovation. CEE this year recognized two financial office staff members, financial coordinator Nancy Cook and senior financial administrator Mary Ellen Sinkus, for their tireless work, often behind the scenes, on everything from complex research proposals to ensuring the overall financial health of the department.

Markus J. Buehler
Department Head
McAfee Professor of Engineering