# Department of Mechanical Engineering

The Department of Mechanical Engineering (MechE) at MIT embodies the Institute motto *mens et manus*, "mind and hand," through uncompromising analysis, hands-on discovery, and an unrelenting commitment to making the world a better place. MechE is where concepts become products, start-ups, and solutions. Its faculty conduct fundamental research and develop innovative tools to address the challenges of today and tomorrow in the areas of health, environment, energy, and security.

To meet these challenges, MechE students and faculty take a collaborative approach, conducting research at the boundaries of seven core engineering disciplines:

1. Mechanics: modeling, experimentation, and computation
2. Design, manufacturing, and product development
3. Controls, instrumentation, and robotics
4. Energy science and engineering
5. Ocean science and engineering
6. Bioengineering
7. Micro and nano engineering

These core disciplines shape MechE's world-class introductory and advanced undergraduate- and graduate-level programs. MechE students learn by doing, experiencing a level of understanding that can only occur through creation. These programs combine in-depth analysis, based on classical mechanical principles, with cutting-edge design and manufacturing techniques. Students receive not only a rigorous academic education, but also first-hand experience and exposure to the latest research.

Every year, MechE attracts and enrolls top-notch students. Both the undergraduate and graduate programs continue to thrive, illustrating a sustained and broad interest in mechanical engineering, with 551 undergraduate students and 567 graduate students enrolled during AY2017—for a grand total of 1,118 students during the same period. MechE research programs incorporate a growing postdoctoral population of approximately 80 fellows and associates.

This report provides an overview of departmental news throughout AY2017. The report includes a short synopsis of new initiatives and strategic plans; updates on faculty news (promotions, retirements, and deaths); select research highlights across the department; an overview of start-ups and products originating from the MechE community; education highlights, with brief overviews of undergraduate and graduate programs; awards and recognition, providing a small sampling of the diversity, breadth, and depth of achievements of the entire MechE community; a brief summary of communications activities; and, finally, an overview of space renovations completed on campus.

## Goals, Objectives, and Priorities

### Strategic Planning Committee

Over the course of the past year, one of the department's top priorities has been organizing various strategic planning activities. Under the leadership of co-chairs Professor Pierre Lermusiaux and Professor Evelyn Wang, a team of 10 tenured associate professors served on the Strategic Planning Committee. The committee conducted a thorough examination of the department's strengths, weaknesses, challenges, and opportunities. For a comprehensive overview, the committee conducted more than fifty interviews with key stakeholders, including faculty, research scientists, instructors, staff, students, alumni, industry partners, and donors. There were also a number of open forms and surveys organized. The goal was to develop a strategy that shapes the future of mechanical engineering and identifies the important questions and challenges that the department will face in order to continue to be leaders in the world.

Findings and recommendations were organized into four main pillars: education, research, operations, and general identity and brand. Within the research pillar, four overarching MechE "grand challenges" were identified to drive collaborative research, foster both individual and collective breakthroughs on issues with global impact, and increase funding opportunities. These challenges were chosen because MechE is uniquely poised to solve them through leveraging the department's existing strengths and activities. The MechE grand challenges include:

> **Design and Manufacturing Innovation for the Future**, with a goal of designing innovative products and systems that address societal challenges in health, environment, and sustainability for humanity.
>
> **Global Energy Sustainability**, with a goal of achieving a sustainable supply and use of energy for our world, and lowering carbon dioxide emissions.
>
> **Health of the Planet**, with a goal of ensuring health and security of our oceans and environment, and of our water and food supplies.
>
> **Robotics, Autonomy, and Information Systems for the World**, with a goal of creating automated and smart mechanical systems for health, transportation, energy, and the environment.

Over the course of the next academic year, various recommendations and new initiatives stemming from the Strategic Planning Committee's report will be implemented across the department, a few of which are mentioned below.

## New Initiatives

### Consolidating Courses

One of the initiatives that came out of the Strategic Planning Committee was to consolidate foundation core classes across Course 2 and Course 2-A. This consolidation will reduce overlapping courses and optimize the number of classes offered by MechE, thereby increasing the efficiency and effectiveness of teaching. Plans are also underway for new undergraduate and graduate courses to ensure the department continues to provide excellent teaching and learning opportunities to students.

### MechE Alliance Program

The Strategic Planning Committee also recommended the launch of the MechE Alliance Program. Under the leadership of Joe Rife ’66, SM ’68, PhD ’74, the MechE Alliance Program bridges the gap between students, alumni, and industry by establishing mentor relationships. Activities both on and off campus provide valuable opportunities for alumni and industry partners to engage with the Course 2 community. The MechE Alliance Program seeks to establish a community of engaged alumni who can provide career advising, mentorship, and possibly career opportunities to the student population.

### MechE Grand Challenge Research Workshops and Hiring

A number of workshops that align with important MechE questions and challenges are in the planning stages. These workshops will provide an overview of the work being done to address those areas chosen as priorities for MechE. Additionally, these questions and challenges will help guide the hiring of new MechE faculty as the department continues to grow and develop.

## Faculty Promotions

### Associate Professor to Full Professor

Pierre Lermusiaux was promoted to full professor. He is an international leader in the broad area of ocean data assimilation. His group’s activities encompass many diverse aspects of numerical modeling, uncertainty quantification, and data assimilation, with applications to quantitative prediction of ocean dynamics on multiple length and time scales. His key contributions include the construction of dynamically orthogonal equations to efficiently quantify uncertainty in large geophysical systems, the development of new multi-resolution high-order numerical schemes, and more recently, path planning for autonomous marine platforms. He is broadly recognized as a thought leader and one of the most technically sophisticated researchers at the intersection of oceanographic observation and modeling. His creativity and ideas have been influential in multiple Office of Naval Research initiatives. The technical advances of his group allow for real-time ocean modeling and forecasting, and many of his innovations are being integrated into large-scale ocean forecasting programs and real-time naval coastal monitoring operations. Lermusiaux’s work also has important societal impact for fisheries, marine industry, energy, national security and conservation, and, ultimately, for the assessment of human impacts on the ocean’s health and on climate.

Evelyn Wang, the Gail E. Kendall Professor in the Department of Mechanical Engineering, was promoted to full professor. She is an internationally recognized leader in phase change heat transfer on nanostructured surfaces. Her research combines fundamental studies of micro/nanoscale heat transport processes with the development of novel engineered surfaces and materials to create high-performance thermal management, thermal energy storage, and energy conversion devices. Wang has provided outstanding service to MIT and her profession. She co-leads MechE’s Strategic Planning Committee and the MechE and Lincoln Laboratory Task Force, and she served as the associate director of Microsystems Technology Laboratory. She co-founded the Gordon Research Conference on Micro and Nanoscale Phase Change Heat Transfer. She mentored a large group of graduate students and postdocs, eight of whom are

now faculty members. Since receiving tenure, she was selected as an American Society of Mechanical Engineers (ASME) fellow and a member of the Defense Science Study Group. She received the ASME Electronics Packaging Division Outstanding Women in Engineering Award, as well as three best paper/poster awards.

### Associate Professor Without Tenure to Associate Professor with Tenure

Cullen Buie, the Esther and Harold E. Edgerton Career Development Professor in the Department of Mechanical Engineering, was promoted to associate professor with tenure. He works to exploit microscale, electric-field-driven transport phenomena for applications in biotechnology, fluid mechanics, and energy. His research is applicable to a diverse range of problems, from anti-biofouling surfaces and biofuels to energy storage and bacterial infections.

A. John Hart SM ’02, PhD ’06, the Mitsui Career Development Professor in Contemporary Technology in the Department of Mechanical Engineering, was promoted to associate professor with tenure. He works on carbon nanotubes and graphene, 3-D printing, and other additive manufacturing processes, as well as origami-inspired engineering, to enable new technologies ranging from consumer electronics and medical devices to art objects.

Xuanhe Zhao, the Robert N. Noyce Career Development Professor in the Department of Mechanical Engineering, was promoted to associate professor with tenure. He performs research that has led to the design of extremely tough adhesive and biocompatible hydrogels and hydrogel-solid hybrids, the discovery of new failure mechanisms in dielectric polymers, and controlled crumpling and unfolding of large-area 2-D materials into functional nanostructures.

### Assistant Professor to Associate Professor without Tenure

Themistoklis (Themis) Sapsis has been promoted to associate professor without tenure. Sapsis works in the area of statistical estimation for nonlinear dynamical systems, including prediction and quantification of rare events, with application to predicting rogue waves and turbulent flows in the ocean. His research encompasses the analysis, modeling, and optimization of ocean systems and processes using stochastic methods. His work has great practical importance for a wide range of important problems in ocean engineering, including the design of ships and offshore structures. He has also made strong educational contributions via his teaching in the 2N Naval Construction and Engineering curriculum. He is the recipient of numerous awards, including the 2016 Air Force Office of Scientific Research Young Investigator Award.

Amos Winter has been promoted to associate professor without tenure. Winter is a leader in the field of development engineering, which seeks creative solutions to persistent challenges in the developing world. His research focuses on understanding the unique technical and socioeconomic constraints that underlie global issues. Winter adopts these constraints to motivate his scientific research program, which ranges from mechanics to machine design. He then uses the fundamental insights gained to create innovations that deliver high performance at low cost and serve as global product platforms appropriate for communities that span the global economic spectrum. Winter has designed and implemented a number of technologies for

emerging markets, including prosthetics, drip irrigation, and small-scale desalination. He has commercialized these emerging market solutions in the US and, in the process, developed basic principles for the growing field of "reverse innovation." In recognition of this foundational work, Winter (along with his co-author Vijay Govindarajan) received the McKinsey Award for best article in Harvard Business Review in 2015. Winter is also a devoted teacher and mentor. He co-leads 2.007, MechE's flagship undergraduate introductory design course, in which he has implemented a number of pedagogical innovations including "physical homework" and the Inspired Engineering lecture. In addition, he has developed a graduate-level machine and product design class, 2.76 Global Engineering, that teaches MIT students how to apply their technical skills within the unique technical and socioeconomic constraints of emerging global markets.

### Principal Research Scientist to Senior Research Scientist

Yuming Liu was promoted from Principal Research Scientist to senior research scientist. Liu is a world-class expert on wave hydromechanics, which is foundational to applications in ocean science and engineering. Liu's work is centered on developing new theoretical and computational methodologies which have yielded fundamental insights of critical importance to industrial applications. These include perturbation theory and nonlinear computations for the design and analysis of ships and offshore platforms; high-order, phase-resolved predictions of wave-field evolution; and analysis of mixed liquid-gas flows in marine risers. Liu has published dozens of impactful papers in top journals. He is a core contributor to MechE's Ocean Science and Engineering Area and he has established his own research agenda, raised significant funding, and supervised the highest quality students and postdocs. He is cited by a number of faculty as a highly sought-out and productive collaborator. Liu has been a valued team player, including contributing to teaching and service in the ocean area.

## Chairs and Professorships

Michael Triantafyllou has been named the Henry L. and Grace Doherty Chair in Ocean Science and Engineering.

Alexander Slocum, who held the Neil and Jane Pappalardo Professorship, has been appointed as the inaugural holder of the Walter M. May and A. Hazel May Professorship. This professorship has been established to award an outstanding faculty member who is a leader in emerging technologies with an emphasis on societal needs.

Anette "Peko" Hosoi has been appointed as the Neil and Jane Pappalardo Professor of Mechanical Engineering.

Irmgard Bischofberger has been appointed to an Edgerton Professorship, a Career Development Chair.

## Faculty Retirements

Chryssostomos Chryssostomidis retired in January 2017 after serving for 47 years on the MIT faculty. Chryssostomidis served as the longest-tenured director of MIT Sea Grant for 35 years. During that time, he helped Sea Grant grow and established the Autonomous Underwater Vehicles Lab and the Sea Perch Program. He also served

as department head of Ocean Engineering from 1994 to 2002. Throughout his career, Chryssostomidis has made many contributions to ocean engineering research. He was appointed as the Henry L. Doherty Professor in Ocean Science and Engineering. He is a member of the Royal Institute of Naval Architects and a fellow of the Society of Naval Architects and Marine Engineers.

## Faculty Deaths

Ernesto E. Blanco, professor emeritus of mechanical engineering, passed away on March 21, 2017, in Murrieta, California at the age of 94. Over the span of a half-century, Blanco designed a number of groundbreaking devices that aided people with physical disabilities—including the first stair-climbing wheelchair and an improved Braille typewriter. He also invented trocars for endoscopic procedures and ophthalmological surgical tools. During his nearly 38 years at MIT, Blanco developed a reputation as a consummate educator who treated every student, faculty, and staff member with the utmost care and respect.

*Professor Emeritus Ernesto Blanco in 2011. Credit: Dominick Reuter.*

Ira Dyer, professor emeritus of ocean engineering, died peacefully at his home on October 9, 2016, at the age of 91. Dyer's distinguished career, with a specialty in acoustics, spanned over six decades. His seminal research had profound impacts in the fields of aeroacoustics, structural acoustics, and underwater acoustics. Dyer was a valued educator and mentor for many students who are now prominent scientists, and he served as head of MIT's Department of Ocean Engineering (which later merged with MechE) for 10 years.

J. Karl Hedrick, James Marshall Wells Academic Chair and professor of mechanical engineering, passed away on February 22, 2017, after a long battle with lung cancer. He was 72 years old. From 1974 to 1988, Hedrick was a professor of mechanical engineering at MIT, where he also directed the Vehicle Dynamics Laboratory. Hedrick was best known for the development of nonlinear control theory and its applications to transportation, including automated highway systems, power train controls, embedded software design, formation flight of autonomous vehicles, and active suspension systems.

Dean Alden Horn, a retired US Navy captain, director of MIT Sea Grant College Program from 1976 to 1982, and MIT alumnus, passed away on July 13, 2016, in North Carolina at the age of 95. Horn had a 27-year distinguished career as an officer in the US Navy. He also oversaw MIT Sea Grant when it received its coveted college program status—the first private institution to achieve this—and he was the executive officer for two international Arctic research programs.

## Research Highlights

MechE faculty are innovators and problem solvers, always with an eye toward developing technologies that will make the world a better place. As noted above, researchers are focused on major global challenges including health, the environment, energy, and security. Below is a snapshot of the varied and diverse research conducted in the department.

### Evelyn Wang

Technologies exist for extracting water from very moist air, such as "fog harvesting" systems that have been deployed in a number of coastal locations. There are very expensive ways of removing moisture from drier air. However, this new method is the first that has potential for widespread use in virtually any location, regardless of humidity levels, the researchers say. They have developed a completely passive system that is based on a foam-like material that draws moisture into its pores and is powered entirely by solar heat.

The findings are reported in the journal Science by a team including Evelyn Wang, MIT postdoc Sameer Rao, graduate student Hyunho Kim, research scientists Sungwoo Yang and Shankar Narayanan (currently at Rensselaer Polytechnic Institute), and alumnus Ari Umans SM '15.

### Jeewan Kim

A new technique developed by MIT engineers may vastly reduce the overall cost of wafer technology and enable devices made from more exotic, higher-performing semiconductor materials than conventional silicon. As reported in *Nature*, the new method uses graphene—single-atom-thin sheets of graphite—as a sort of "copy machine" to transfer intricate crystalline patterns from an underlying semiconductor wafer to a top layer of identical material.

The engineers worked out carefully controlled procedures to place single sheets of graphene onto an expensive wafer. They then grew semiconducting material over the graphene layer. They found that graphene is thin enough to appear electrically invisible, allowing the top layer to see through the graphene to the underlying crystalline wafer, imprinting its patterns without being influenced by the graphene.

### Gang Chen

Eschewing the traditional kettle and flame, MIT engineers have invented a bubble-wrapped, sponge-like device that soaks up natural sunlight and heats water to boiling temperatures, generating steam through its pores. The design, which the researchers call a "solar vapor generator," requires no expensive mirrors or lenses to concentrate the sunlight, but instead relies on a combination of relatively low-tech materials to capture

ambient sunlight and concentrate it as heat. The heat is then directed toward the pores of the sponge, which draw water up and release it as steam.

The low-tech design may provide inexpensive alternatives for applications ranging from desalination and residential water heating, to wastewater treatment and medical tool sterilization. The team has published its results in *Nature Energy*. The research was led by George Ni, an MIT graduate student, and Gang Chen, the Carl Richard Soderberg Professor in Power Engineering and the head of MechE.

### Amos Winter

Engineers at MIT have found a way to cut the cost of solar-powered drip systems by half by optimizing the drippers. Furthermore, these new drippers can halve the pumping power required to irrigate, lowering energy bills for farmers. The team modified the drippers' dimensions in a way that significantly reduces the pressure required to pump water through the entire system, while still delivering the same amount of water.

The team, led by Winter, plans to further modify the system upstream, optimizing the tubing, filters, pumps, and solar power system to ultimately make drip irrigation affordable for farmers in developing regions of the world.

### Ian Hunter

Artificial muscles—materials that contract and expand somewhat like muscle fibers do—can have many applications, from robotics to components in the automobile and aviation industries. in which a material reproduces some of the bending motions that natural muscle tissues perform. The key ingredient, cheap and ubiquitous, is ordinary nylon fiber.

The new approach to harnessing this basic synthetic fiber material lies in shaping and heating the fibers in a particular way, which is described in a new paper in the journal *Advanced Materials* by Seyed Mirvakili, a doctoral candidate, and Ian Hunter, the George N. Hatsopoulos Professor in the Department of Mechanical Engineering.

### A. John Hart and Gareth McKinley

Engineers at MIT have invented a fast, precise printing process that may make electronic surfaces an inexpensive reality. In a paper published in *Science Advances*, the researchers report that they have fabricated a stamp made from forests of carbon nanotubes that is able to print electronic inks onto rigid and flexible surfaces.

A. John Hart says the team's stamping process should be able to print transistors small enough to control individual pixels in high-resolution displays and touchscreens. The new printing technique may also offer a relatively cheap, fast way to manufacture electronic surfaces for as-yet-unknown applications.

### Yang Shao-Horn

Energy storage devices called supercapacitors have become a hot area of research, in part because they can be charged rapidly and deliver intense bursts of power. However, all supercapacitors currently use components made of carbon, which require high temperatures and harsh chemicals to produce.

Now researchers at MIT and elsewhere have for the first time developed a supercapacitor that uses no conductive carbon at all, and that could potentially produce more power than existing versions of this technology. The team's findings are reported in the journal *Nature Materials*, in a paper by Mircea Dincă, associate professor of chemistry at MIT; Yang Shao-Horn, the W.M. Keck Professor of Energy; and four others.

### Anette "Peko" Hosoi

Engineers at MIT and their collaborators have designed a microfluidic device they call a "tree-on-a-chip," which mimics the pumping mechanism of trees and plants. Like its natural counterparts, the chip operates passively, requiring no moving parts or external pumps. It is able to pump water and sugars through the chip at a steady flow rate for several days. The results were published in *Nature Plants*.

Anette "Peko" Hosoi, professor and associate department head for operations in MechE, says the chip's passive pumping may be leveraged as a simple hydraulic actuator for small robots. Engineers have found it difficult and expensive to make tiny, movable parts and pumps to power complex movements in small robots. The team's new pumping mechanism may enable robots whose motions are propelled by inexpensive, sugar-powered pumps.

### Cullen Buie

Using high-resolution imaging, MechE researchers observed the effect of raindrops falling on dry soil laden with bacteria. When falling at speeds mimicking those of a light rain, at temperatures similar to those in tropical regions, the drops released a spray of mist, or aerosols. Each aerosol carried up to several thousand bacteria from the soil. The researchers found the bacteria remained alive for more than an hour afterward. If the airborne bacteria were lofted further by wind, it could travel a good distance before settling back on the ground to colonize a new location, says Cullen Buie.

### Kripa Varanasi

When farmers spray their fields with pesticides or other treatments, only two percent of the spray sticks to the plants. A significant portion of it typically bounces right off the plants, lands on the ground, and becomes part of the runoff that flows to streams and rivers—often causing serious pollution. But a team of MIT researchers aims to fix that.

By using a clever combination of two inexpensive additives to the spray, the researchers found they can drastically cut down on the amount of liquid that bounces off. The findings appear in the journal *Nature Communications*, in a paper by Kripa Varanasi, associate professor of mechanical engineering; Maher Damak, graduate student; Seyed Reza Mahmoudi, research scientist; and M. Nasim Hyder, former postdoc.

### Nicholas Fang

Engineers from MIT and Singapore University of Technology and Design are using light to print 3-D structures that "remember" their original shapes. Even after being stretched, twisted, and bent at extreme angles, the structures—from small coils and multi-material flowers to an inch-tall replica of the Eiffel Tower—sprang back to their original forms within seconds of being heated to a certain temperature.

For some structures, the researchers were able to print micron-scale features as small as the diameter of a human hair—dimensions that are at least one-tenth as big as what others have been able to achieve with printable shape-memory materials. The team's results were published in the online journal *Scientific Reports*.

### Roger Kamm

Researchers at MIT's research center in Singapore have developed a new microfluidic device that tests the effects of electric fields on cancer cells. They observed that a range of low-intensity, middle-frequency electric fields effectively stopped breast and lung cancer cells from growing and spreading, while having no adverse effect on neighboring healthy cells.

The device, about the size of a US dollar coin, is designed to help scientists narrow in on safe ranges of electric fields to noninvasively treat breast, lung, and other forms of cancer. The results are published online in *Scientific Reports*.

### Rohit Karnik

MIT engineers have fabricated a functional dialysis membrane from a sheet of graphene—a single layer of carbon atoms, linked end to end in hexagonal configuration like that of chicken wire. The graphene membrane, about the size of a fingernail, is less than 1 nanometer thick. (The thinnest existing membranes are about 20 nanometers thick.) The team's membrane is able to filter out nanometer-sized molecules from aqueous solutions up to 10 times faster than state-of-the-art membranes, with the graphene itself being up to 100 times faster.

While graphene has largely been explored for applications in electronics, Piran Kidambi, a postdoc in MechE, says the team's findings demonstrate that graphene may improve membrane technology, particularly for lab-scale separation processes and potentially for hemodialysis.

### Xuanhe Zhao

Researchers from MIT and Harvard Medical School have developed a biocompatible and highly stretchable optical fiber made from hydrogel—an elastic, rubbery material composed mostly of water. The fiber, which is as bendable as a rope of licorice, may one day be implanted in the body to deliver therapeutic pulses of light or light up at the first sign of disease. The researchers say the fiber may serve as a long-lasting implant that would bend and twist with the body without breaking down. The team has published its results online in the journal *Advanced Materials*.

## Startup and Product Highlights

MechE faculty, students, and alumni have founded many innovative start-ups and launched a number of game-changing products. Here we provide an overview of the various start-ups and products launched by a member of the MechE community which have been highlighted by MIT News over the past year.

### Coffee Cookie

*MIT seniors Victoria Gregory and Gabe Alba with their product, Coffee Cookie. Credit: Dana Smith Photography.*

Inspired by their work in 2.009, MIT students Gabe Alba and Victoria Gregory founded Coffee Cookie, a lightweight, circular object that attaches to the bottom of disposable coffee cups. It looks like a sea-blue casino chip, but it is a battery-operated drink warmer that heats up to 90 degrees Celsius.

### Glyde

In 2012, a team of students in MIT's well-known product-design class, Course 2.009, invented a hand truck with fold-out treads and a braking system that made hauling kegs downstairs safer and easier. Now that hand truck, which launched commercially in April and is called the Glyde, is already being used by hundreds of people worldwide. The MIT spinout selling the product, ELL Operations, has landed major partnerships with Anheuser-Busch InBev and leading hand-truck manufacturer Magliner.

### Jolt Sensor

MechE alumnus Ben Harvatine '12—who suffered several head injuries as a longtime wrestler—started selling a wearable sensor for athletes, called the Jolt Sensor, that detects and gathers data on head impacts in real-time. Commercialized through Harvatine's startup Jolt Athletics, the sensor is now being used nationwide by teams from grade-school to college levels and is being trialed by professional teams.

### Smarking

Co-founded by MechE alum Wen Sang PhD ’14 and MIT alum Maokai Lin PhD ’14, Smarking has developed a data-analytics platform that crunches available parking data to help parking managers monitor spaces and revenue in real-time. By pulling in data on external factors such as weather and events, the platform also predicts future demand, so managers can optimize staffing and adjust pricing to boost revenue.

### Common Sensing

Common Sensing aims to solve the nation’s diabetes-management issues by going digital. The startup’s smart insulin-pen cap logs insulin intake data on an app and in the cloud, to help patients better manage their regimen. Moreover, the cap gives doctors a detailed view into patients’ insulin habits and how they affect blood-glucose levels, for more targeted care.

### Squirrel Devices

MechE PhD candidates Pranay Jain and Anshul Singhal co-founded Squirrel Devices to tackle the problem that 75% of the blind and low-vision community is unemployed in the United States and is significantly underrepresented in the growing fields of science, technology, engineering, and math. Their first instrument aims to make geometry’s continuous shapes and lengths measurable with a plastic sliding caliper that enables students with significant visual impairments to read measurements in Braille, as one would on a regular ruler.

### New Valence Robotics

Co-founded by MechE alum Alfonso (A.J.) Perez ’13, MEng ’14, New Valence Robotics (NVBOTS) has brought to market the only fully-automated, commercial 3-D printer that is equipped with cloud-based queuing and automatic part removal, making print jobs quicker and easier for multiple users, and dropping the cost per part.

### Ministry of Supply

MechE alum Kevin Rustagi ’11 co-founded Ministry of Supply, a Boston-based innovator of high-tech fashion. The company has developed a rapidly growing science-based clothing line and the industry’s first 3-D robotic knitting machine.

### Open Water Power

Open Water Power (OWP), which was co-founded by MechE alum Ian Salmon McKay ’12, SM ’13, aims to greatly improve the range of unpiloted underwater vehicles (UUVs), helping them better perform in a range of applications under the sea. Recently acquired by major tech firm L3 Technologies, OWP has developed a novel aluminum-water power system that is safer and more durable, and that gives UUVs a tenfold increase in range over traditional lithium-ion batteries used for the same applications.

## Event Highlights

MechE hosts a number of seminal events throughout the year. Below are highlights from some of the larger, more high-profile events throughout the AY2017:

### Mechanical Engineering Research Exhibition, September 16, 2016

The third annual Mechanical Engineering Research Exhibition (MERE) showcased graduate student research projects. Eighty participants, representing all seven of the department's key research areas, gathered in Walker Memorial. More than 200 people, including many local alumni, came to take in the showcases, which also included projects from the department's new student-run makerspace, MakerWorks.

### International Symposium on Academic Makerspaces, November 13-16, 2016

In 2015, Professor Martin Culpepper, MechE "maker czar," went on a national listening tour and visited his counterparts at other universities—sharing his own knowledge and learning how MIT could work differently. In November, he brought the listening tour together and launched the International Symposium on Academic Makerspaces (ISAM). This three-day academic conference at MIT brought together professors, machine operators, students, and administrators to talk about their shared opportunities and distinct challenges. ISAM drew 340 attendees from 115 universities on every continent except for Antarctica. With sessions dedicated to culture and community, safety, faculty outreach, space-planning, budgeting and fundraising, and campus politics, among others, presenters offered varied, sometimes diverging, opinions.

### 2.009 Final Class Presentations, December 12, 2016

The theme for this year's student projects in the mechanical engineering class called Product Engineering Processes was "rough, tough, and messy," but the student teams' product ideas were much more pleasant and positive than that may sound: All eight were designed to be life-saving or health-enhancing, or at least lots of fun.

Three of the products introduced, in a raucous, enthusiastic, and music-filled set of final class presentations in MIT's Kresge Auditorium, were designed to assist people with medical conditions or physical limitations, and two others were intended to be protective equipment for workers. The remaining three products were: a device to prevent ice dams on roofs, a fun new interactive arcade game for kids, and a musical device.

Now in its 21st year, the class, known by its course number, 2.009, is led by Professor of Mechanical Engineering David Wallace and a large team of assistants and mentors. It is designed to give its students—140 of them this term—a strong sense of what's involved in taking a product all the way from brainstorming ideas, through preliminary design and testing, to a final, fully functional product design and a basic business plan. Along the way, students build a strong sense of teamwork and learn to collaborate effectively.

## 2.007 Final Robot Competition, May 11, 2017

*Professor Sangbae Kim and Associate Professor Amos Winter carry the winner of the 2017 2.007 Student Design Robot Competition. Credit: Tony Pulsone.*

In one of MIT's most eagerly awaited annual events, dozens of robots designed and built by undergraduates in a mechanical engineering class endured hours of intense competition as they scrambled to rack up points in one-on-one clashes on special Star Wars-themed playing arenas.

As has often happened in these contests—which have been going on, and constantly evolving, since 1970—the ultimate winner in the single-elimination tournament was not the one that had most consistently racked up the highest scores all evening. Rather, it was a high-scoring bot that triumphed when its competitor missed a crucial scoring opportunity because its starting position was just slightly out of alignment.

The class, 2.007 Design and Manufacturing I, which has 165 students (mostly sophomores), begins by giving each student an identical kit of parts, from which they each have to create a robot to carry out a variety of tasks to score points. This year, in a nod to the 40th anniversary of the first Star Wars film, released in 1977, the robots crawled around and over a replica of a Star Wars X-wing Starfighter. Students could earn points by pulling up a sliding frame to rescue prisoners trapped in carbonite; by dumping Imperial stormtroopers into a trash trench; by activating a cantina band; or by spinning up one or both of two large cylindrical thrusters on the wings. Students could choose which tasks to have their robot try to accomplish, and had just one semester to design, test, and operate their bot.

The devices could be pre-programmed to carry out set tasks and could also be manually controlled through a radio-linked controller. As in past years, the open-ended nature of the assignment—and the variety of different ways to score—led to a wide range of strategies and designs, spanning from tall towers that would extend by telescoping out or with hinged sections, to elevator-like lifting devices, to small and nimble bots that scurried around to carry out multiple tasks, to an array of arms and devices for grasping or turning the different pieces.

## Education Highlights

### Undergraduate Enrollment, AY2012–AY2016

| Degree program | AY2012 | AY2013 | AY2014 | AY2015 | AY2016 |
|---|---|---|---|---|---|
| Sophomores course 2 | 78 | 84 | 87 | 85 | 88 |
| Sophomores course 2-A | 62 | 98 | 86 | 85 | 99 |
| Sophomores course 2-OE | 5 | 3 | 4 | 7 | 1 |
| **Sophomores subtotal** | **145** | **185** | **177** | **177** | **188** |
| Juniors course 2 | 90 | 80 | 94 | 89 | 83 |
| Juniors course 2-A | 67 | 61 | 102 | 102 | 92 |
| Juniors course 2-OE | 3 | 6 | 4 | 3 | 3 |
| **Juniors subtotal** | **160** | **147** | **200** | **194** | **177** |
| Seniors course 2 | 79 | 87 | 73 | 92 | 81 |
| Seniors course 2-A | 64 | 68 | 66 | 104 | 89 |
| Seniors course 2-OE | 3 | 4 | 8 | 5 | 6 |
| **Seniors subtotal** | **146** | **159** | **147** | **201** | **176** |
| 5th-year students course 2 | 5 | 8 | 11 | 4 | 3 |
| 5th-year students course 2-A | 10 | 7 | 12 | 7 | 7 |
| 5th-year students course 2-OE | 0 | 0 | 1 | 3 | 0 |
| **5th-year students subtotal** | **15** | **15** | **24** | **14** | **10** |
| **Total** | **466** | **506** | **548** | **586** | **551** |

### Graduate Enrollment, AY2012–AY2016

| Degree program | AY2012 | AY2013 | AY2014 | AY2015 | AY2016 |
|---|---|---|---|---|---|
| Master's | 240 | 232 | 230 | 193 | 213 |
| Doctoral | 255 | 299 | 310 | 312 | 309 |
| MEng | 17 | 15 | 18 | 12 | 15 |
| MechEng | 2 | 0 | 0 | 0 | 0 |
| Eng (naval) | 30 | 33 | 33 | 34 | 30 |
| **Total** | **542** | **579** | **591** | **551** | **567** |

## Honors and Recognition

### Faculty Awards

Professor Lallit Anand was awarded the J.P. Den Hartog Distinguished Educator Award, conferred for excellence in teaching mechanical engineering, serving as an inspiration for students, and fostering the development of physical insight and engineering judgment.

Professor Gang Chen, department head, was awarded the Eringen Medal by the Society of Engineering Science for his seminal contributions to the understanding of nanoscale transport and energy conversion phenomena, and their applications in energy storage and conversion, as well as thermal management. Chen also received as a 2016 Thomson Reuters Highly Cited Researcher. Additionally, Chen was honored by the student-driven

Committed to Caring (C2C) program. Started in the spring of 2014, Commited to Caring seeks to recognize and celebrate MIT faculty members who go above and beyond to make an impact in the lives of graduate students.

Associate Professor Domitilla Del Vecchio as well as Assistant Professor Betar Gallant each received a Professor Amar G. Bose Research Grant.

Professor Ahmed Ghoniem has been selected as one of the most recent honorees of the C2C program. Also, Ghoniem has been elected as an American Physical Society Fellow for his contributions to computational fluid dynamics.

Associate Professor A. John Hart won a Ruth and Joel Spira Award for Excellence in Teaching, which acknowledges "the tradition of high-quality engineering education at MIT."

Assistant Professor Alexie Kolpak has been awarded a 2017 National Science Foundation Faculty Early Career Development Award, given to early career researchers who are talented educators and conduct groundbreaking research.

Professor Gareth McKinley was awarded the J.P. Den Hartog Distinguished Educator Award, conferred for excellence in teaching mechanical engineering.

Professor Emeritus Jerome Milgram received the 2017 Gibbs Brothers Medal from the National Academy of Sciences for his work in naval architecture and marine engineering.

Assistant Professor Stefanie Mueller was included in the 2017 Forbes "30 Under 30" list for her work on the computer science of "physical data," such as that involved in 3D printing.

Professor David Parks was awarded the Daniel C. Drucker Medal by the American Society of Mechanical Engineers (ASME) for seminal contributions to the formulation of constitutive theories and computational procedures for large inelastic deformation and failure of metals and polymers.

Professor Nicholas Patrikalakis received the Pierre Bezier Award from the Solid Modeling Society for "essential contributions in the area of shape processing and interrogation, recasting many related problems as solutions of nonlinear polynomial systems."

Associate Professor Pedro Reis was awarded the American Physical Society Early Career Award for Soft Matter Research for seminal experimental and numerical contributions to the understanding of elastic instabilities and geometric nonlinearities in soft matter.

Professor Yang Shao-Horn was honored as a 2016 Thomson Reuters Highly Cited Researcher.

Professor Alexander Slocum was elected to the National Academy of Engineering for contributions to precision machine design and manufacturing across multiple industries and leadership in engineering education. He won the Capers and Marion McDonald Award for Excellence in Mentoring and Advising, given to a faculty member who has demonstrated a lasting commitment to personal and professional development. Additionally, he was honored by the C2C program.

Professor Kripa Varanasi won the Distinguished Achievement Award from TMS Energy Materials for "Distinguished Achievements in Interfacial Science and Energy Materials." Varanasi and his students won the Audience Choice Award at the MIT 100K Accelerate contest for their product Infinite Cooling, which is based on the research they are conducting on water capture.

Professor Evelyn Wang was awarded the Gustus L. Larson Memorial Award by the American Society of Mechanical Engineers (ASME) for outstanding achievement in mechanical engineering. Additionally, Wang's new solar device that converts heat to focused beams of light and could create cheap and continuous power was named as one of MIT Technology Review's 10 "Breakthrough Technologies of 2017."

Associate Professor Amos Winter has been awarded the 2016-2017 Harold E. Edgerton Faculty Achievement Award in recognition of exceptional distinctions in teaching, research, and service. Winter was also awarded a 2017 NSF Faculty Early Career Development (CAREER) Award, given to early career researchers who are talented educators and conduct groundbreaking research. Additionally, Winter won the Junior Bose Award for being an outstanding contributor to education among the junior faculty of the School of Engineering.

Associate Professor Maria Yang has been named a 2017 MacVicar Fellow. This undergraduate teaching award is given in recognition of outstanding teaching, mentoring, and education innovation.

Professor Ioannis Yannas was elected to the National Academy of Engineering for co-developing the first commercially reproducible artificial skin that facilities new growth, saving the lives of thousands of burn victims.

Associate Professor Xuanhe Zhao received the 2017 Young Investigator Medal from the Society of Engineering Science and the 2017 Young Scientist Award from the Adhesion Society.

## Student Awards

### Lemelson-MIT Student Prizes

- Katy Olesnavage was awarded the Lemelson-MIT Student Prize for her new design method for a low-cost, high-performance, passive prosthetic foot.
- Natasha Wright received the Lemelson-MIT Student Prize for her work improving drinking-water quality and understanding household water-usage habits in rural India.
- Seniors Grace Li, Jessica (Jialin) Shi, and Charlene Xia and their team won the Lemelson-MIT Student Prize for creating a real-time text-to-Braille converter.

*Lemelson-MIT Student Prize Winner Katy Olesnavage. Credit: Bryce Vickmark*

### Marshall Scholar

Senior Matthew Cavuto has been named a 2017 Marshall Scholar. As a Marshall Scholar, Cavuto will engage in advanced prosthetic and assistive technology research over the course of two years of study in the UK at Imperial College London and Cambridge University.

### World Technology Award

PhD candidate Maher Damak was named the winner of the environment category at the World Technology Awards for his research on reducing runoff of agricultural pesticides by making sprays stickier.

### Siebel Foundation Scholars for 2017

PhD candidate Hung Nguyen has been named one of the 2017 Siebel Foundation Scholars, for his academic achievements, leadership, and commitments to addressing crucial global challenges.

### Schwarzman Scholar

Senior Melody Liu has been named a Schwarzman Scholar. She is among the 129 members of the program's class of 2018, who will pursue a year of study and leadership training at Tsinghua University in Beijing. Her vision is to innovate in the space of manufacturing robotics within industry, working with international companies.

### Tomorrow's Engineering Leaders: The 20 Twenties

Graduate student Kristen Railey '13 was awarded as one of "Tomorrow's Engineering Leaders: The 20 Twenties" by Aviation Week.

### 2017 Forbes 30 Under 30 List

Graduate student John Lewandowski was named one of Forbes 30 Under 30 in the social entrepreneurs category. He is founder of the Disease Diagnostic Group, which screens patients for malaria in just five seconds with a reusable handheld device.

## Rankings and Departmental Awards

The department has received number one subject rankings for 2017 for both graduate and undergraduate programs from *US News and World Report* and the QS World University Rankings.

Additionally, multimedia specialist John Freidah was honored with a Boston/New England Emmy in the Health/Science Program/Special category for the short film, *Water is Life*, which chronicles PhD student Natasha Wright and Professor Amos Winter as they travel to India, gathering research on how to design a low-cost desalination system for use in developing areas. The film was also recently honored with a 2017 National Edward R. Murrow Award—one of the most prestigious awards in journalism—as well as a 2017 Circle of Excellence Award from the Council for Advancement and Support of Education.


*Multimedia Specialist John Freidah wins an Emmy Award. Credit: Eric Antoniou*

## Communications

The MechE media team continued to share the department's stories in compelling ways across a variety of channels this past year. Highlights included increases in social media followers and website traffic, as well as a redesign of the print and electronic versions of the departmental newsletter, MechE Connects.

### Social Media

MechE's social media audience reach increased throughout AY2017. Its Facebook reach continued to grow as MechE's page received 6,776 new followers, representing a 32% increase from July 1, 2016. The MechE Twitter audience increased 41% with 1,080 new followers. Meanwhile, the department's Instagram account has seen growth since reactivating in May 2017 with 1,141 followers, and often reaches a 10% engagement rate.

### Website Traffic

The recently redesigned MechE homepage is constantly updated with engaging content, including articles about groundbreaking research, student and faculty profiles, start-up and product news, and award highlights. Website traffic has increased at a steady rate. Page views went up 18% in AY2017, from 2,998,025 in the previous year to 3,540,593 in the current year. Pages per session also saw an increase of 23%, from 5.26 in AY 2016 to 6.46 in AY2017.

### YouTube Traffic

The media team continued its focus on producing high-quality, informative, and captivating videos that capture the department's culture and groundbreaking research. Watch time on the MechE YouTube channel increased 32% from 343,301 (Y2016) to 454,418 (AY2017); views increased 41% from 141,962 (AY2016) to 200,086 (AY2017); and subscriptions rose 90% over the past year from 7,726 (AY2016) to 14,649 (AY2017).

## Space Renovations

### Biomechanics Lab (Room 5-025)

This year, Room 5-025, which had been assigned to Associate Professor Alexandra Techet, has been converted into a lab space for incoming Assistant Professor and d'Arbeloff Career Development Professor Ming Guo. Techet was moved to Room1-225. Room 5-025 has been converted to a new biomechanics lab for Guo. The space uses the existing infrastructure and consists of two new spaces—one dark space with confocal microscope and the other with a cell culture space. A biosafety safety cabinet and laser shades were installed, along with an eyewash and safety showers. Construction is now complete and the lab is fully operational.

### Toy Design Lab

The Toy Design Lab was relocated from temporary space in Building 35 to space in Building 3 (Rooms 3-003, 3-003A, 3-004, and 3-008). The total size of the project is approximately 2,175 square feet, of which 1,175 square feet is teaching and workshop space. The scope includes new glass along the corridor wall, new corridor flooring, and the removal of abandoned in place ductwork, piping and wiring to provide a new open ceiling in the area. Approximately 1,000 square feet of corridor improvement in this area has been undertaken by the project. The project is now complete and the move from Building 35 to Building 3 has been accomplished. This space will be used extensively for MechE's design build classes, overflow from 2.009 in the fall and 2.00B in the spring. The Toy Design Lab provides contiguous space to the Pappalardo Lab, which hosts other design classes held in the department.

### Building 31

Building 31 underwent a complete renovation, with the Department of Aeronautics and Astronautics and MechE being the primary occupants of the space. MechE created new, renovated lab space for Amos Winter on the first floor of Building 31. Other principal investigators (PIs) occupying lab space include the Sloan Automotive Lab (PIs: Wai Cheng, Victor Wong, and Tian Tian), Ahmed Ghoniem, and Yang Shao-Horn. Incoming faculty members Sili Deng and Asegun Henry will also have their labs located in Building 31. The second floor consists of office space and shared student seating. The third floor includes a dry lab space, shared wet lab space, shared student seating, and shared bench space. The dry lab will be assigned to incoming faculty member Asegun Henry in fall 2018. Occupancy for Building 31 is scheduled for the end of August 2017.

## Conclusion

The Department of Mechanical Engineering continues to represent *mind*, *hand*, and—as MechE alumna Megan Smith insightfully noted in her 2015 commencement speech—*heart*, in everything it does, upholding all the principles that make it one of the strongest MechE departments in the world: an unyielding dedication to research and educational excellence, a passion for hands-on learning, a flair for innovation, and a real desire to do good in the world—all supported by a strong network of ecosystems. The various initiatives and grand challenges carried out by the Strategic Planning Committee will shape the upcoming year and enable MechE to continue its position as one of the best mechanical engineering programs in the world.

**Gang Chen**
**Department Head**
**Carl Richard Soderberg Professor of Power Engineering**

**Anette "Peko" Hosoi**
**Associate Department Head for Operations**
**Neil and Jane Pappalardo Professor of Mechanical Engineering**