Department of Mechanical Engineering

In the Department of Mechanical Engineering (MechE), we are makers and innovators, embodying the MIT motto *Mens et manus* (mind and hand)—as well as "heart"—through uncompromising analysis, hands-on discovery, and an unrelenting commitment to making the world a better place.

Our faculty conduct fundamental research and develop innovative tools to address the grand challenges of today and tomorrow in the areas of health, the environment, innovation, energy, and security.

To meet these challenges, we coordinate research in the department across seven collaborative disciplinary areas: mechanics (modeling, experimentation, and computation); design, manufacturing, and product development; controls, instrumentation, and robotics; energy science and engineering; ocean science and engineering; bioengineering; and micro and nano engineering.

Creativity and innovation fuel our research, but they also imbue our classrooms where our students learn by doing, experiencing a level of understanding that can only occur through creation. They receive not only a rigorous academic education but also first-hand experience and exposure to cutting-edge research.

Led by Professor Sanjay Sarma, vice president for open learning, we are "flipping the classroom" to bring web-based learning technologies to our students, allowing us to dedicate more classroom time to the type of hands-on education that is so fundamental to the MechE curriculum. We were one of the first departments at MIT to offer our classes as massive open online courses (MOOCs) as part of the online edX platform.

Every year, we attract and enroll top-notch mechanical engineering students. Both our undergraduate and graduate programs continue to thrive, illustrating a sustained and broad interest in mechanical engineering, with 558 undergraduate students and 595 graduate students enrolled during AY2016 academic year, for a grand total of more than 1,153 students. Our research programs incorporate a growing postdoctoral population of approximately 120 fellows and associates.

In this year's report, we provide snapshots of departmental news and contributions over the past year, including a short synopsis of faculty news (hires, promotions, and deaths); selected research highlights across the department and associated faculty profile videos; education highlights, with brief overviews of our undergraduate and graduate programs; and finally awards and recognitions to provide a small sampling of the diversity, breadth, and depth of achievements of the entire Department of Mechanical Engineering community.

Faculty

We are very pleased to announce the hires of Irmgard Bischofberger, Ming Guo, and Jeehwan Kim as assistant professors, as well as that of Jonathan Page, USN, to associate professor of the practice of naval construction. We are also very pleased to announce the promotion of Sangbae Kim from the rank of associate professor without tenure to associate professor with tenure; the promotions of Konstantin Turitsyn, Kenneth Kamrin, and Themistoklis Sapsis from assistant professor to associate professor; and the promotion of Thomas Peacock from associate professor to full professor. Each brings a unique expertise to the department and the Institute in terms of their individual achievements and contributions to research, education, mentorship, and service.

New Faculty

Assistant Professor Irmgard Bischofberger received her BSc and MSc in 2006 and her PhD in 2011, all in physics, from the University of Fribourg, Switzerland. She worked as a postdoctoral researcher at the University of Chicago in the research group of Sidney Nagel. She is the recipient of a Kadanoff-Rice Postdoctoral Fellowship at the University of Chicago and a Swiss National Science Foundation Postdoctoral Fellowship, as well as an American Physical Society Gallery of Fluid Motion Poster Prize. Bischofberger works in the area of fluid dynamics and soft matter physics, with a focus on formation of patterns from instabilities in fluid and technological systems. In her graduate work, she studied the phase behavior and solvation properties of thermo-sensitive polymers. As a postdoc working for Sidney Nagel at the University of Chicago, she discovered proportional growth—a new growth pattern that was not observed in physical systems, despite its common occurrence in biological systems. Bischofberger is also an enthusiastic champion for science education. She began as an assistant professor in January 2016.

Assistant Professor Ming Guo received his BE and ME degrees in 2004 and 2007, respectively, in engineering mechanics from Tsinghua University, and an MS and PhD in 2012 and 2014 from Harvard University. He studied for his PhD under the supervision of David Weitz, working on problems in cell biomechanics, and his PhD research investigated the mechanical and dynamic properties of living mammalian cells, with an emphasis on intracellular mechanics and forces, the mechanics of cytoskeletal polymers, the equation of state of living cells, and the effect of cell volume and intracellular crowding on cell mechanics and gene expression. In his PhD thesis research, Ming discovered that there is a direct relationship between cell stiffness and volume. By varying the cell volume through a number of different techniques, Ming showed that the volume of cells is a much better predictor of their stiffness than any other cue. He developed a method to measure the mechanical properties and overall motor forces inside living cells by monitoring the fluctuation of microbeads inside the cells and delineating the timescales under which the contribution of active cellular processes could be distinguished from passive mechanical properties. Ming began as an assistant professor in August 2015.

Assistant Professor Jeehwan Kim received his BS in material science from Hongik University in 1997, his MS in material science from Seoul National University in 1999, and his PhD in material science from UCLA in 2008. Since 2008 he has been a research staff member at IBM Thomas J. Watson Research Center in Yorktown Heights, New York, conducting research in photovoltaics, 2-D materials, graphene, and advanced complementary metal–oxide–semiconductor devices. Jeehwan has been named a master inventor at IBM for his prolific creativity, filing more than 100 patents in five years. He has made several breakthrough contributions, including a demonstration of the ability to peel large-area, single-crystal graphene grown from a silicon carbide substrate, enabling reuse of the expensive substrate; the successful growth of gallium nitride on graphene with 25% lattice mismatch, demonstrating that gallium nitride films grown from the process function as well as LEDs, pointing to a new principle for growing common semiconductors for flexible electronics; and achieving high efficiency in silicon polymer tandem solar cells and 3-D solar cells. Jeehwan began as an assistant professor in September 2015.

Associate Professor Lieutenant Commander Jonathan Page graduated from the Naval Academy in 2002, was commissioned a member of the Surface Warfare Officer Community, and served onboard the USS Stethem (a guided missile destroyer) before transferring to the Engineering Duty Officer (EDO) community in 2005. As an EDO he served from 2005 to 2008 as project manager, docking officer, and business officer in San Diego, California, working on major repair and maintenance projects on several classes of Navy ships. From 2008 to 2011, Page was a student in our 2N Naval Construction and Engineering program, where he completed the degrees of Master of Science in Engineering and Management and Naval Engineer. Page's MIT thesis research investigated the use of real option analysis to provide flexibility and cost savings in the early stage design of US Navy ships. After graduation from MIT, Page reported to the Program Executive Office for Ships, in the Program Management Office for the USS Zumwalt (DDG 1000), the most complex guided missile destroyer ever constructed. In this role, he had responsibility for all technical decisions related to the program. From 2014 to present, Page has been an officer-in-charge for shipbuilding, conversion and repair at the Naval Shipyard in San Diego as well as the program manager's representative for the construction of the new Mobile Landing Platform. He is an excellent choice for a two-year tour as associate professor of the practice of naval construction in our 2N Naval Construction and Engineering program.

Faculty Promotions

Assistant Professor to Associate Professor Without Tenure

Associate Professor Kenneth Kamrin received his SB from UC Berkeley in 2003 and his PhD from MIT in 2008. Kamrin was a National Science Foundation (NSF) Postdoctoral Fellow at Harvard University (2008–2011) and joined the MIT faculty in January 2011. Kamrin is a rising star and has made seminal contributions to the modeling of dense granular flows. This is an area that is of importance to many industrial and geological processes. He has advanced continuum constitutive models for granular flow and has developed numerical techniques to address challenges in simulating granular flow. He has demonstrated that a wide range of granular flow experimental data can be described by a continuum constitutive equation including nonlocal effect. He is an excellent teacher and co-developed the first concurrently online class offered to MIT students, including online proctoring, office hours, and a searchable video index. Kamrin is the recipient of the NSF CAREER Award, and the American Society of Mechanical Engineers Eshelby Mechanics Award for Young Faculty.

Associate Professor Themistoklis (Themis) Sapsis earned his diploma in naval architecture and marine engineering from the National Technical University of Athens in 2005 and his PhD in mechanical and ocean engineering from MIT in 2010. From 2011 to 2013, he was an assistant research scientist at the Courant Institute of Mathematical Sciences, NYU, and joined the MIT Mechanical Engineering Department as an assistant professor in 2013. 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 problems in ocean engineering, including the design of ships and offshore structures. He has also made strong educational contributions via his teaching in our 2N Naval Construction and Engineering program. He is the recipient of numerous awards including a Sloan Research Fellowship in Ocean Sciences, the Army Research Office Young Investigator Award, the Office of Naval Research Young Investigator Award, and the Air Force Office of Scientific Research Young Investigator Award.

Associate Professor Konstantin (Kostya) Turitsyn obtained his BSc in physics from Novosibirsk State University in 2002, his MSc in theoretical physics from the Moscow Institute of Physics and Technology in 2004, and his PhD from the Landau Institute for theoretical physics in 2007. After his receiving his PhD, Turitsyn was a Kadanoff-Rice Fellow at the University of Chicago from 2007 to 2009 and an Oppenheimer Fellow at the Los Alamos National Lab from 2009 to 2010. He joined our faculty as an assistant professor in 2011. Turitsyn is an international leader in the development of novel mathematical techniques for the analysis of complex nonlinear and stochastic systems. He has developed new theoretical tools for challenging problems across a wide variety of domains, including statistical physics, fluid mechanics, optics, and power engineering. As a graduate student and postdoc, Turitsyn developed theoretically rigorous microscopic descriptions of the stochastic dynamics of complex fluids, including polymers, vesicles, and blood cells. He also investigated the dynamic collapse of gas cavities, the dynamics of plugs in microfluidic channels, and nonlinear waves in optical fibers. Since joining our faculty, Turitsyn has launched a new research program in the nonlinear dynamics of power systems, with a primary focus on improving power grid robustness. His contributions in this area include a new method for fast and reliable N-2 contingency screening in the power grid and a new technique for the assessing transient stability in power systems. Turitsyn has made strong teaching contributions to our undergraduate dynamics subjects, and is one of our first faculty members to make extensive use of the MITx online education platform to benefit MIT residential students.

Associate Professor Without Tenure to Associate Professor With Tenure

Associate Professor Sangbae Kim is a world leader in the design of biomimetic robot systems. Professor Kim earned his BS at Yonsei University in Korea in 2001 and both his MS and PhD at Stanford University (mentored by Professor Mark Cutkosky) in 2004 and 2008, respectively. He then performed research for one year at Harvard University as a postdoc with Professor Rob Wood. Kim joined our faculty as an assistant professor in June of 2009, and was promoted to associate professor without tenure in July 2014. Kim’s high-impact contributions have established him as a world leader in biomimetic robotics—the study of the structure and function of biological systems as models for the design and engineering of novel robotic systems. Inspired by the magnificent locomotive capabilities of animals, Kim develops new design methodologies that systematically exploit relevant biological principles and implement them in novel robotic designs. His work analyzes the intersection of animal function and robotic capabilities, in order to leverage functionality that is uniquely robotic yet derived from eons of successful animal evolution. In doing so, he has created a series of inspirational, award-winning robots—most notably the MIT Cheetah—that embody new approaches to design and actuation that can be applied for other types of challenging robot design problems. His work has strongly influenced the field of dynamic robots and has attracted worldwide attention from media and students. He is a passionate educator who has made strong contributions to our design curriculum. Kim is the recipient of many awards, including the ICRA Best Student Paper Award (2007), the King-Sun Fu Memorial Best Transactions on Robotics Paper (2008), the DARPA Young Faculty Award (2013), the NSF Career Award (2014), and the Ruth and Joel Spira Award for Distinguished Teaching at MIT (2015).

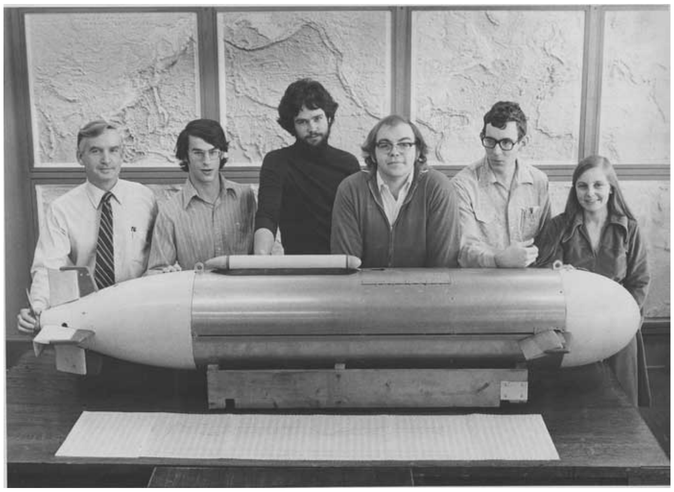
Associate Professor With Tenure to Full Professor

Professor Tom Peacock received his BSc from the University of Manchester in 1994 and his PhD from Oxford University in 1998. He was a research associate at the University of Colorado from 1998 to 1999 and an instructor in the MIT Mathematics Department from 2000 to 2003. He joined our department as an assistant professor in 2003 and was promoted to tenured associate professor in 2010. Peacock's research focuses on the dynamics of density-stratified fluids, and nonlinear dynamics with applications to the ocean. A common thread throughout his research is the interplay between laboratory experiments, theoretical modeling, and shipboard field studies. This powerful combination enables Peacock to develop and test theoretical hypotheses, pursue challenging nonlinear regimes where theory typically breaks down, and ground his research in real-world scenarios. He is an international leader in internal waves. His work in this area has helped to resolve a longstanding debate about the nature of the generation mechanism of internal solitary waves in the South China Sea. Professor Peacock is an excellent teacher and a strong contributor to the MIT community. Within the Mechanical Engineering Department, he led the renovation of the third floor of Building 3, and serves now as the media mogul of the department. In this role, he led the complete redesign of the MechE website. At the Institute level, he is a member of the Distinguished Scholarship Committee, the Committee on Nominations, and he volunteers as a freshman advisor.

Faculty Deaths

A. Douglas Carmichael, a professor emeritus in the Department of Mechanical Engineering, passed away peacefully on November 9, 2015. He was 86.

Professor Emeritus Carmichael was a highly regarded thermodynamicist with a specialty in steam and gas turbines for ship power and propulsion. A professor of power engineering in the Department of Ocean Engineering at MIT from 1970 to 1996, he was a lead developer of the first MIT autonomous underwater vehicle. He was also well known at MIT for his mentorship and dedication to undergraduate students.



The late Professor A. Douglas Carmichael, left, posed with his students in 1975 behind one of the first autonomous underwater vehicles built at MIT. Photo courtesy of MIT Museum.

Dr. Koichi Masubuchi, a professor emeritus of Ocean Engineering, passed away on April 1, 2016, in Concord, Massachusetts. He was of 92.

Professor Emeritus Masubuchi was a leading expert in welding science and fabrication technology whose work helped to progress the understanding of welding and the important role it plays in marine and aerospace structures. He spent his first 10 years at MIT focused on solving welding problems NASA was having with its Apollo project. His main areas of expertise were in heat flow, residual stresses, and distortion in weldments; the fracture of welded structures; and welding technologies for underwater and space applications.

Research Highlights

Our faculty are innovators and problem solvers, always with an eye toward developing technologies that will make the world a better place. They are focused on five major global challenges: health, the environment, innovation, energy, and security. Here we provide a snapshot of the varied and diverse research conducted in the department.

Alexie Kolpak

Researchers make an important step toward widespread adoption of water splitting to produce hydrogen fuel, an attractive alternative to fossil fuels. A team of researchers, led by Assistant Professor Alexie Kolpak, has found that mobilizing oxygen atoms from the crystal surface of perovskite-oxide electrodes to participate in the formation of oxygen gas is key to speeding up water-splitting reactions. Their work is crucial for the widespread adoption of water splitting to produce hydrogen fuel, an attractive way to depart from traditional energy sources such as fossil fuels toward clean, renewable energy sources. The researchers studied perovskite oxide catalysts consisting of varying proportions of lanthanum and strontium with cobalt and oxygen, and identified two key parameters governing the catalytic performance of these materials: the covalency of the cobalt–oxygen bond and the number of oxygen vacancies. They then tuned their synthesis parameters to demonstrate that one particular material, strontium cobaltite ($SrCoO_{2.7}$), exhibits highly active water electrolysis, much faster than state-of-the-art catalyst iridium oxide, which contains precious metals. Through collaboration with MIT theorists, the team unraveled how the reaction occurs on the atomic scale.

Themistoklis Sapsis

New prediction tool gives two to three minute warning of incoming rogue waves. Sailing history is rife with tales of monster-sized, rogue waves—huge, towering walls of water that seemingly rise up from nothing to dwarf, then deluge vessel and crew. Rogue waves can measure eight times higher than the surrounding seas and can strike in otherwise calm waters, with virtually no warning. Now a prediction tool developed by Assistant Professor Themis Sapsis may give sailors a two- to three-minute warning of an incoming rogue wave, providing them with enough time to shut down essential operations on a ship or offshore platform. The tool, in the form of an algorithm, sifts through data from surrounding waves to spot clusters of waves that may develop into a rogue wave. Depending on a wave group's length and height, the algorithm computes a probability that the group will turn into a rogue wave within the next few minutes.

Cullen Buie

New microfluidic device may speed up DNA insertion in bacteria, the first step in genetic engineering. Genetically engineering any organism requires first getting its cells to take in foreign DNA. To do this, scientists often perform a process called electroporation, in which they expose cells to an electric field. If that field is at just the right magnitude, it will open up pores within the cell membrane through which DNA can flow. But it can take scientists months or even years to figure out the exact electric field conditions to reversibly unlock a membrane's pores. A new microfluidic device developed by Associate Professor Cullen Buie may help scientists quickly home in on the electric field "sweet spot"—the range of electric potentials that will harmlessly and temporarily open up membrane pores to let in DNA. In principle, the simple device could be used on any microorganism or cell, significantly speeding up the first step in genetic engineering.

Seth Lloyd

System for handling massive digital datasets could make impossibly complex problems solvable. From gene mapping to space exploration, humanity continues to generate ever-larger sets of data—far more information than people can actually process, manage, or understand. Machine learning systems can help researchers deal with this ever-growing flood of information, but even with the most powerful modern supercomputers, such problems remain daunting and impractical to solve. Now, a new approach that would use quantum computers to streamline these problems has been developed by a team led by Professor Seth Lloyd. The new quantum-based approach could exponentially speed up such calculations. For example, if you have a dataset with 300 points, a conventional approach to analyzing all the topological features in that system would require "a computer the size of the universe," says Lloyd. In other words, the problem is simply not solvable in that way. "That's where our algorithm kicks in," he says. Solving the same problem with the new system, using a quantum computer, would require just 300 quantum bits—and according to Lloyd, a device this size may be achieved in the next few years.

Kamal Youcef-Toumi

New microscope creates near-real-time videos of nanoscale processes. State-of-the-art atomic force microscopes (AFMs) are designed to capture images of structures as small as a fraction of a nanometer—a million times smaller than the width of a human hair. In recent years, AFMs have produced desktop-worthy close-ups of atom-sized structures, from single strands of DNA to individual hydrogen bonds between molecules. But scanning these images is a meticulous, time-consuming process. AFMs therefore have been used mostly to image static samples, as they are too slow to capture active, changing environments. Now a team led by Professor Youcef-Toumi has designed an atomic force microscope that scans images 2,000 times faster than existing commercial models. With this new high-speed instrument, the team produced images of chemical processes taking place at the nanoscale, at a rate that is close to real-time video.

Xuanhe Zhao

Water-based "Band-Aid" senses temperature, lights up, and delivers medicine to the skin. A team led by Associate Professor Xuanhe Zhao has designed what may be the bandage of the future: a sticky, stretchy, gel-like material that can incorporate temperature sensors, LED lights, and other electronics, as well as tiny, drug-delivering reservoirs and channels. The "smart wound dressing" releases medicine in response to changes in skin temperature and can be designed to light up if, say, medicine is running low. When the dressing is applied to a highly flexible area, such as the elbow or knee, it stretches with the body, keeping the embedded electronics functional and intact. The key to the design is a hydrogel matrix designed by Xuanhe Zhao—a rubbery material, mostly composed of water, designed to bond strongly to surfaces such as gold, titanium, aluminum, silicon, glass, and ceramic. Xuanhe Zhao says electronics coated in hydrogel may be used not just on the surface of the skin but also inside the body, for example as implanted, biocompatible glucose sensors, or even soft, compliant neural probes.

Rohit Karnik

Like biological channels, graphene pores are selective for certain types of ions. The surface of a single cell contains hundreds of tiny pores, or ion channels, each of which is a portal for specific ions. Ion channels are typically about 1 nanometer wide; by maintaining the right balance of ions, they keep cells healthy and stable. Now a team led by Professor Rohit Karnik has created tiny pores in single sheets of graphene that have an array of preferences and characteristics similar to those of ion channels in living cells. Each graphene pore is less than two nanometers wide, making them among the smallest pores through which scientists have ever studied ion flow. Each is also uniquely selective, preferring to transport certain ions over others through the graphene layer. Professor Karnik says graphene nanopores could be useful as sensors or in mining.

Alberto Rodriguez

Engineers use the environment to give simple robotic grippers more dexterity. Most robots on a factory floor are fairly ham-handed: Equipped with large pincers or claws, they are designed to perform simple maneuvers, such as grabbing an object, and placing it somewhere else in an assembly line. More complex movements, such as adjusting the grasp on an object, are still out of reach for many industrial robots. A team led by Assistant Professor Alberto Rodriguez now hit upon a way to impart more dexterity to simple robotic grippers: using the environment as a helping hand. The team has developed a model that predicts the force with which a robotic gripper needs to push against various fixtures in the environment in order to adjust its grasp on an object.

John Leonard

Robots' maps of their environments can make existing object-recognition algorithms more accurate. Professor John Leonard's research group specializes in SLAM, or simultaneous localization and mapping, the technique whereby mobile autonomous robots map their environments and determine their locations. Last July, at the Robotics Science and Systems conference, members of Professor Leonard's group presented a new paper demonstrating how SLAM can be used to improve object-recognition systems, which will be a vital component of future robots that have to manipulate the objects around them in arbitrary ways. The system uses SLAM information to augment existing object-recognition algorithms, and its performance should thus continue to improve as computer vision researchers develop better recognition software and roboticists develop better SLAM software.

Ian Hunter

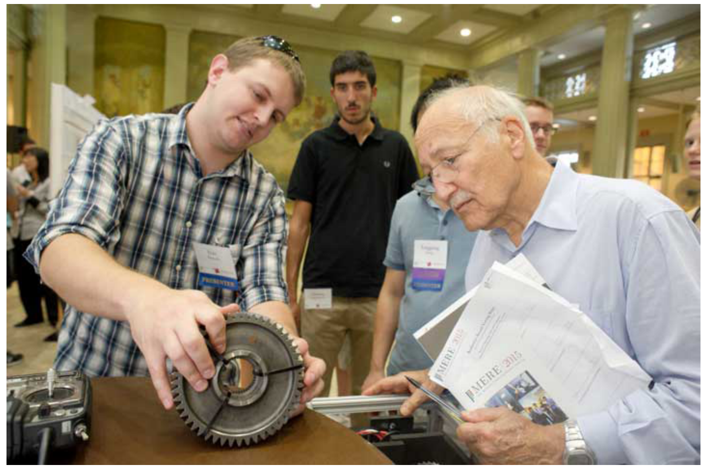
Yarns of niobium nanowire can make supercapacitors to provide a surge of energy when it's needed. Wearable electronic devices for health and fitness monitoring are a rapidly growing area of consumer electronics; one of their biggest limitations is the capacity of their tiny batteries to deliver enough power to transmit data. Now, Professor Ian Hunter has found a promising new approach to making supercapacitors that has the potential to deliver the short but intense bursts of power needed by such small devices. The new approach uses yarns, made from nanowires of the element niobium, as the electrodes in tiny supercapacitors (which are essentially pairs of electrically conducting fibers with an insulator between). They may also be useful for other applications where high power is needed in small volumes, such as autonomous microrobots.

Event Highlights

Second Annual Mechanical Engineering Research Exhibition

On a hot fall day in September, MechE graduate students were carefully hanging up their posters along the perimeter of Walker Memorial's main room. More than 125 alumni and their guests were finishing up lunch and conversation, starting to direct their attention to the students setting up monitors and machines on tables in front of them. The first presentation session for the second annual Mechanical Engineering Research Exhibition (MERE) was about to begin.

Unlike most research exhibitions, MERE is not primarily about the research itself; instead, alumni, students, and staff who volunteer as judges are tasked with deciding how well the student presenters communicate understanding of their research, its impact on the world, and excitement about what they're doing.

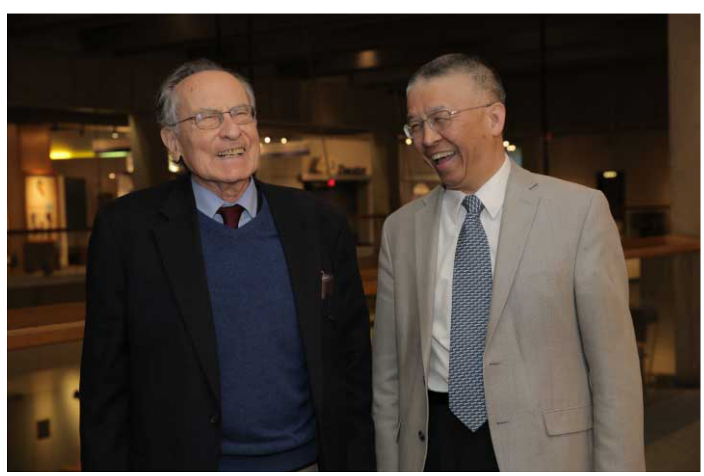


The event, which was held for the first time in fall 2014, is organized by the Graduate Association for Mechanical Engineers and sponsored by MechE. Its purpose is to give graduate students a chance to practice communicating their research to various audiences and receive feedback on their presentation. Just as importantly, it also offers the entire MechE community a chance to learn about current research in the department and network with alumni, faculty, students, and staff.

This year, more than 80 MechE graduate students presented their research, and more than 450 members of the MechE community attended the event. MechE alum Eric Wilhelm '99, SM '01, PhD '04, founder of the popular company Instructables—an online community where makers can share their projects and connect with each other—gave the keynote address.

Hope Regenerated Premiere at the Museum of Science

On Monday, April 4, 2016, MechE hosted an event at the Museum of Science to celebrate the career of Professor Ioannis V. Yannas and his induction into the National Inventors Hall of Fame in 2015 for his discovery of a method to regenerate human skin. The event began with a private reception for close friends of the department, followed by a premiere of the Boston/New England Emmy Award-winning video *Hope Regenerated*, by multimedia specialist John Freidah. The video chronicles Professor Yannas's discovery and its impact on the lives of children with life-threatening burns.



After the premiere, MechE hosted a panel discussion titled "Into the Hands of Those in Need," featuring Professor Yannas; Matthias Donelan, MD, Chief of Staff of Shriners Hospitals for Children, Boston; Professor Neville Hogan, MSc '73, MENg '76, PhD '77; Professor Alexander Slocum, '82, SM '83, PhD '85; Assistant Professor Amos Winter, SM '05, PhD '11; and alumna Danielle Zurovcik, SM '07, PhD '12, CEO, Worldwide Innovative Healthcare, Inc. The panel was moderated by Associate Professor Domitilla Del Vecchio and was followed by a reception. Despite a spring snow storm, more than 80 students, staff, alumni, and friends attended the event to honor Professor Yannas, of whom we could not be prouder. His willingness to collaborate outside his comfort zone with Dr. John Burke, MD; the persistence he showed in the face of failure; and the lasting impact their discovery has had on the lives of burn victims are an inspiration to us all. The method Dr. Burke and Professor Yannas discovered for regenerating human organs transformed burn care and generated new fields of medicine and engineering. It will continue to light the way toward new discoveries and advances in bioengineering well into the future.

Education Highlights

Undergraduate Enrollment, AY2012–AY2016

Degree program	AY2012	AY2013	AY2014	AY2015	AY2016
Sophomores					
2	78	84	87	85	80
2-A	62	98	86	85	97
2-OE	5	3	4	7	2
Subtotal	145	185	177	177	179
Juniors					
2	90	80	94	89	85
2-A	67	61	102	102	81
2-OE	3	6	4	3	8
Subtotal	160	147	200	194	174
Seniors					
2	79	87	73	92	79
2-A	64	68	66	104	100
2-OE	3	4	8	5	3
Subtotal	146	159	147	201	182
5th-year Students					
2	5	8	11	4	8
2-A	10	7	12	7	15
2-OE	0	0	1	3	0
Subtotal	15	15	24	14	23
Total	**466**	**506**	**548**	**586**	**558**

Graduate Enrollment, AY2012–AY2016

Degree program	AY2012	AY2013	AY2014	AY2015	AY2016
Master's	240	232	230	193	224
Doctoral	255	299	310	312	327
MEng	17	15	18	12	14
MechEng	0	0	0	0	1
Eng (naval)	30	33	33	34	29
Total	**542**	**579**	**591**	**551**	**595**

2.007—The Birth of a Hands-On Education

It's hard to ignore the fact that a worldwide maker movement is well underway. Over the past 10 or so years, community Maker Faires have become all the rage; fabrication shops have popped up around the world for both professionals and hobbyists; and websites, tools, and toys catering to do-it-yourselfers are on the rise.

It's easy to appreciate how a love for making became wildly popular again, especially as science, technology, engineering, art, and math (STEAM) education is increasingly and passionately promoted and embraced around the world. Of course, at MIT—particularly in the Department of Mechanical Engineering—it's been this way since 1865.

It was around that time that MIT was founded by scientist and educator William Barton Rogers, who had a different idea about how to educate and learn. He founded MIT to teach not only the ability to think critically but also how to apply that thinking to real-world problems—to teach craftsmen and farmers as well as engineers and academics. So the motto was coined (*Mens et manus*, or mind and hand), the seal was drawn (the scholar and the smith). From that moment on, it's been in MechE's DNA to upend traditional ways of teaching and to democratize science and technology for the betterment of all.

By the 1970s, when Professor Emeritus Woodie Flowers was transforming course 2.70—now 2.007 Design and Manufacturing I—into a project-based, get-your-hands-dirty experience, MechE's reputation for innovative education was already solidified. Yet the magnitude of transforming a design and manufacturing class from a mostly pencil-and-paper experience to one of fun and hands-on building was a profound paradigm shift in engineering education.

Knowledge is of course essential, Flowers says, because uninformed imagination can be quite dangerous, but at the same time, "nobody is getting hired to solve the multiple-choice problems at the end of the chapter." He created a class to prepare students not only to design an object but also to build it. From the beginning, 2.007 was meant to develop students' competence and self-confidence as design engineers, while emphasizing the creative design process and the application of physical laws.

"I learned from my father that doing things in a different way was often fruitful, and the underpinnings of all my educational efforts is to allow people a path to change their self-image," Flowers says. "Students might struggle with equations and other rigorous elements of an MIT education, but in 2.007 they can be superstars."

The first challenges were purely mechanical traps and contraptions, using a universal set of materials predetermined by Flowers, and the students loved it. Their creations went head-to-head at end-of-year competitions that became the most attended events at the Institute. Since then, several faculty members have followed in Flowers's footsteps as instructor of 2.70/2.007, including Professor Emeritus David Gordon Wilson; former Professor Harry West; Professor Alex Slocum; and Professor Daniel Frey, each imbuing the class with a bit of their own style and personality. Along the way, the contraption competition became a robot competition, mechanical components became electromechanical ones, wires became remote controllers, and autonomous robotics challenges were introduced.

And yet, said Assistant Professor Amos Winter, "The fundamental principles of 2.007 haven't changed. Because core mechanical principles like forces, energy, bearings, and shafts work the same as they always have and haven't gone out of style. Whether a car uses internal combustion or is a hybrid, it still comes down to transferring power to the road."

In 2013, Professor Daniel Frey passed the torch to Associate Professor Sangbae Kim and Assistant Professor Winter, who are co-instructing the class. Kim is a renowned expert in biomimetics and robotics, and Winter is a leader in designing technologies for developing and emerging markets. Together the two have made several curriculum updates to the class, including eliminating exams and adding weekly written homework, weekly physical homework, and an oral design review. As is the tradition now, the class ends in a final robot competition in which students compete against each other to see whose robot can win the most points. Each student is required to enter the competition, but only 32 finalists will enter the ring on competition day.

"The most exciting thing about 2.007 is that the students get to build their own personal robot and compete in front of an audience of more than 500 people," Kim says. "We create a new theme every year, having in mind a particular physical task that will require the students to apply the theories they've learned to specific engineering functions and transfer their knowledge from paper to working robot."

This spring's competition was called Hack to the Future, a nod to the classic film *Back to the Future*, which had its 30th anniversary fall 2015. Using a universal kit of tools and materials, students were challenged to build a robot that could collect plutonium, climb the clock tower, slide Doc Brown down a cable, and open a DeLorean car door. As always students each developed their own strategies for gaining points, and the student whose robot earned the most points at the end of each duel progressed to the next round until there was only one champion left standing: Allison Edwards, whose robot was efficient and reliable.

"I hope students in 2.007 walk away from the class with engineering intuition," said Winter. "I want them to go out into the world around them and almost have a kind of superpower—to see what's going on behind face value, like forces, and stresses, and energy transfer. It's that kind of intuition that we try to build by bringing real-world examples into the classroom and showing them how to match theory with what actually happens."

2.013 Engineering Systems Design

With the unstable cost of petroleum perpetually threatening to rise, and its potentially devastating effects on the environment waiting anxiously in the wings, many people are hopeful that electric vehicles will provide a cleaner, cheaper option to diesel- or gasoline-powered vehicles.

But there are still several problems that engineers are working to solve before this hope can become a reality, the most challenging of which is recharging. For many consumers, it's currently a deal breaker, for charging takes too long and is required frequently. And that's assuming that charging stations exist at the necessary distances in the first place. However, undergraduate students in Professor Douglas Hart's 2.013/2.014 Engineering Systems Design and Development capstone sequence are developing a promising solution: aluminum fuel.

"Relative to batteries," says Nicholas Fine, in this year's class, "the amount of energy you can store with aluminum fuel relative to the amount of mass you can carry with you is significantly higher, which means your mission duration is significantly longer." Courses 2.013 and 2.014 started back in 2011 in response to a challenge by MIT Lincoln Laboratories: Develop an energy source for underwater systems that can increase endurance tenfold. The first year's class of students—who worked together under a CEO, as would a real-world design team—discovered that aluminum can react with seawater in a particular way to generate hydrogen gas. The resulting fuel is created by stripping the passivation layer from aluminum using a gallium-based eutectic, then reacting the aluminum with water to generate hydrogen gas and heat.

When this reaction occurs, student David D'Achiardi explained, about half the energy goes into the heat and half goes into the hydrogen. Since hydrogen can be converted to electricity at higher efficiencies than fossil fuels using a fuel cell, and since aluminum is nearly four times as energy dense as diesel, aluminum provides a very safe and efficient energy source without the need to store compressed hydrogen. "But," said D'Achiardi, one of the class's CEOs, "if you are able to recover a portion of the heat energy, your fuel consumption is dramatically decreased, and that is where the fuel becomes extremely interesting as a very high energy-density fuel."

The discovery, originally made by Jonathan Slocum when he was a student in 2.013, led to several progressive underwater autonomous vehicle power systems in subsequent years of the class that could monitor the depths of oceans for weeks at a time. This year's

2.013 class is pursuing other possible applications for the technology, including electric cars. Students have organized themselves into four separate teams, each with their own CEO and their own potential application.

One team, led by Laura Jarin-Lipschitz, is designing a way to use the aluminum fuel to power a submersible power station that rises to the surface to recharge drones for search and rescue missions; another, led by Alexander Klein, is looking at how to automate the production of aluminum fuel and lower its cost; yet another is designing a portable emergency charging device for military situations, led by Fine. The fourth team, led by D'Achiardi, is designing a way to extend the range of electric cars using an onboard, aluminum-fueled generator.

"We want to show that this technology could be comparable, competitive, or possibly even surpass what a gas or diesel vehicle would look like in terms of cost, volume of the fuel, and mass of the fuel," said D'Achiardi. "These are all metrics we are using to shift and propose designs."

His team is working to design a heat-recovery system to take advantage of the heat energy generated, while also trying to devise a way to draw power from the fuel into the battery very quickly, so that electric vehicles can get the same range as fossil-fueled vehicles—all without modifying current electric vehicles. "It's tricky," he said, "because we are trying to generate power inside the vehicle, using this clean technology." Many of the students—some of whom are taking 2.013 for the second time now—plan to continue with the development of their designs in the spring semester with the sister class 2.014.

Honors and Recognition

Faculty

Professor Emeritus Ali S. Argon is the winner of the 2015 Materials Science and Engineering A Journal Prize.

Associate Professors Tonio Buonassisi and Cullen Buie were two of 106 researchers who were recently recognized with the prestigious Presidential Early Career Award for Scientists and Engineers. Buonassisi was also appointed Singapore Research Professor for 2016.

Professor Ahmed Ghoniem was selected to receive the American Institute of Aeronautics and Astronautics Propellants and Combustion Award.

Professor Emeritus John Heywood has been elected as an American Society of Mechanical Engineers Fellow.

Associate Professor Ken Kamrin received this year's Journal of Applied Mechanics Award, as well as the 2016 Spira Award for Distinguished Teaching.

Professor Seth Lloyd was recently appointed the Nam P. Suh Professor of Mechanical Engineering.

Associate Professor Pedro Reis has been selected to receive the Thomas J. R. Hughes Young Investigator Award from the Applied Mechanics Division of the American Society of Mechanical Engineers.

Professor Emanuel Sachs was elected to the National Academy of Engineering.

Assistant Professor Themis Sapsis received the 2016 Young Investigator Award from the Air Force Office of Scientific Research, as well as the 2015 Young Investigator Award from the Army Research Office.

Professor Jean-Jacques Slotine received the 2016 Rufus Oldenburger Medal.

Professor Yang Shao-Horn was recently appointed the W. M. Keck Professor of Energy.

Professor J. Kim Vandiver was selected for a 2016 Consumer Electronics Show Innovation Award.

Associate Professor Kripa Varanasi was selected as one of *Boston Business Journal*'s 40 under 40 for 2015.

Associate Professor Evelyn Wang has been elected as an American Society of Mechanical Engineers Fellow. She was also recently appointed the Gail E. Kendall Professor as well as Singapore Research Professor for 2016.

Assistant Professor Amos Winter received this year's *Harvard Business Review* McKinsey Award for best article.

Associate Professor Maria Yang received this year's Bose Award for excellence in teaching.

Associate Professor Xuanhe Zhao received the 2015 Extreme Mechanics Letters Young Investigator Award.

Undergraduate Students

Alfred A. H. Keil Ocean Engineering Development Award (For Excellence in Broad-Based Research in Ocean Engineering): Brian K. Gilligan and Jorlyn M. Le Garrec

AMP Inc. Award (Outstanding Performance in Course 2.002): Valerie Peng and Daniel E. Rigobon

Carl G. Sontheimer Prize (Creativity and Innovation in Design): Tyler D. Wortman

John C. and Elizabeth J. Chato Award: Camille Henrot

Department Service Award: Sina Booeshaghi, Nicholas W. Kwok, and Aishwarya Narayan

Ernest Cravalho Award (Outstanding Performance in Thermal Fluids Engineering): John H. Bell, Patrick F. Everett, and Elliot D. Owen

International Design Competition (Outstanding Performance in Course 2.007): Austin R. Brown

Lauren Tsai Memorial Award (Academic Excellence by a Graduating Senior): Morgan K. Moroi

Louis N. Tuomala Award (Outstanding Performance in Thermal Fluids Engineering): Martin M. Rencken and Colin M. Poler

Luis de Florez Award (Outstanding Ingenuity and Creativity): Benjamin G. Katz and Moses T. Ort

Mechanical Engineering SuperUROP Award (Outstanding Performance in SuperUROP Program): Bailey R. Montaño

MIT-Lincoln Lab Beaver Works Barbara P. James Memorial Award (Excellence in Project-Based Engineering): Nicholas W. Fine, Camille Henrot, Lauren S. Herring, and Laura Jarin-Lipschitz

Park Award (Outstanding Performance in Manufacturing): Gordon Moseley P. Andrews, and Cody L. Jacobucci

Peter Griffith Prize (Outstanding Experimental Project): Brian P. Wilcox

Robert Bruce Wallace Academic Prize: Trevor R. Day

Whitelaw Prize (Originality in Course 2.007): Beatriz A. Gonzalez, Samuel A. Resnick, James V. Roggeveen, and Kerrie Wu

Wunsch Foundation Silent Hoist and Crane Awards: Kathleen L. Xu

Graduate Students

Carl G. Sontheimer Prize (Creativity and Innovation in Design): Michael Stern

Luis de Florez Award (Outstanding Ingenuity and Creativity): Kathryn M. Olesnavage, and Tyler D. Wortman

Meredith Kamm Memorial Award (Excellence in a Woman Graduate Student): Michelle B. Chen

Thomas Sheridan Prize (Creativity in Man-Machine Integration): Kathryn M. Olesnavage

Wunsch Foundation Silent Hoist and Crane Awards: Riley E. Brandt, Rupak Chakraborty, Lucille Hosford, Julieth Ochoa, Bolin Liao, Katherine M. Ong, David G. Kwabi, Florian J. Feppon, Karim S. Khalil, and Leah R. Mendelson

2016 Tau Beta Pi Inductees

Brittany Bautista
Cyndia Cao
John Drago
Jason Fischman
Elizabeth Mae Glista
Anuj Khandelwal
Melody Liu
Lara Markey
Colleen McCoy
Henry Merrow
Jialin Shi
Krithika Swaminathan
Daniel Vignon

2016 Phi Beta Kappa Inductees

Camille Henrot
Braden Knight
Connie Liu
Andre Wallentin
Kathleen Xu

2016 Pi Tau Sigma Inductees

Natalie Alper
Joseph Babcock
Brittany Bautista
Noam Buckman
Julia Canning
Matthew Cavuto
Justine Cheng
Matthew Chun
Beckett Colson
Tate DeWeese
Isabella DiDio
John Drago
Jason Fischman
Brian Gilligan
Noor Hartono
Sophia Jaffe
Rebecca Kurfess
Lucia Liu
Melody Liu

Joseph Lowman
Henry Merrow
Marie Elimbi Moudio
Maximilian Tang
Lampros Tsontzos

Space Renovations

In continued support of the department's dedication to hands-on education and the community's passion for making, this year we were very pleased to open a brand new, state-of-the-art maker facility: MakerWorkshop. The new space, located in Room 35-122, provides MechE students, staff, and faculty with convenient after-hours access to technology, equipment, and mentorship for academic and hobby projects. It hosts multiple 3-D printers and laser cutters, a water-jet cutter, a mill, a ShopBot, a lathe, electronics fabrication, hand tools, and several other maker tools.

MakerWorkshop is based on the pedagogical belief that the ability to build outside of the classroom is essential to mechanical engineering education, not only for the purpose of applying classroom concepts but also to provide students with the opportunity to learn through experimentation how to work though problems that yield practicable results. The facility will be managed by MechE students, who will also act as mentors for the MechE community and enable the space to function outside of the normal 8 am to 4 pm shop workday to better match student schedules.

The MakerWorkshop staff aims to help nurture the MIT maker community by bringing students together around their passion for making, strengthen hands-on learning within the MIT community, and act as a spearhead for similar efforts around the MIT campus by making the tools, knowledge, and space available to students on their schedules.

The Department of Mechanical Engineering opened MakerWorkshop in partnership with a complementary space, ProtoWorks, in the Martin Trust Center for MIT Entrepreneurship. This partnership creates a synergy among the two spaces, enabling a valuable integration of engineering and entrepreneurship for students of both groups. We are grateful for the support we received in opening MakerWorkshop from the Richard H. Lufkin Memorial Fund, the Martin Trust Center, and the MIT School of Engineering.

Communications

The MechE media team, consisting of Communications Officer Alissa Mallinson, Multimedia Specialist John Freidah, and Webmaster Harris Crist, and led by Professor Thomas Peacock, launched a complete redesign of the MechE website in November 2015. We engaged the design firm, Plain English, and together developed a new site that highlights the department's unique culture and impact on the world, responds fully to all devices, and provides a user-centric and engaging experience for prospective students, alumni, donors, and the general public.

After launching in November, the website saw an increase of 107% in page views over a one-month period (July 2015 vs July 2016), from 132,713 to 274, 654, a 131% increase in pages per session, from 2.82 to 6.54, a 14% increase in average session duration and an 18% decrease in bounce rate. The website won a Silver CASE Circle of Excellence Award in 2016 for the team's redesign strategy and implementation.

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. We look forward to seeing what our faculty and students will discover, solve, and make in the coming year.

Gang Chen
Department Head
Carl Richard Soderberg Professor of Power Engineering

John Leonard
Associate Department Head, Research
Professor of Mechanical and Ocean Engineering

Anette "Peko" Hosoi
Associate Department Head, Education, and Undergraduate Officer
Professor of Mechanical Engineering