MITMECHE

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Massachusetts Institute of Technology

MechEConnects

News from the MIT
Department of Mechanical Engineering

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Innovation and Entrepreneurship: The MechE Way of Life

Curiosity and creativity, together with a *mens et manus* approach, fuel innovation and entrepreneurship in the department.

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MITMECHE

An Entrepreneurial Spirit

Dear Friends,

MIT is a recognized leader in cutting-edge research whose origin and application crosses a number of disciplines. But as our motto *mens et manus* demonstrates, we are also an organization founded on making, building, and doing. This passion for creativity is augmented by a powerful entrepreneurial drive to transfer our inventions from lab to marketplace, ensuring that they become advancements the public can utilize.

In Mechanical Engineering, we integrate product development into a number of our core undergraduate courses, such as 2.009 (Product Engineering Processes) and 2.75 (Medical Device Design). Each year, products developed and prototyped in these courses attract the interest of industry and are brought to market. This connection between innovative design and entrepreneurship is not left to chance. In 2.739 (Product Design and Development), engineers are teamed with designers from the Rhode Island School of Design and management students from MIT's Sloan School of Management to build creative products around a given theme. And the department's custom major, 2A, allows students to incorporate business-focused coursework into a rigorous engineering degree. This entrepreneurial and translational spirit also permeates our research programs. MechE students, post docs, and faculty increasingly seek to translate their research developments into real-world impact directly through startups as well as through engagements with industry.

In this edition of *MechE Connects*, you will read about MechE faculty, alumni, and students who bring their creativity to bear on such diverse projects as water desalination, medical devices, food packaging, order fulfillment, and battery design. What binds them is a passion for discovering new and creative solutions to today's problems, and bringing these innovative, life-changing products to the world's customers.

My own MIT journey began when I came here as a graduate student in 1982 to earn a Master's degree. I was incredibly fortunate to have advisors who encouraged me to pursue the PhD and then to be invited to join the faculty ranks. MIT has enabled me to pursue a career in education, research, service, and leadership at the highest levels – one that I have truly loved and one that I could never have imagined when I came here 31 years ago. The opportunities, the experiences, and the people of MIT have shaped me in many dimensions – intellectually, professionally, and personally.

I am now "graduating" from MIT (it just took me a little longer than each of you!) and have committed to join Columbia University as Dean of the School of Engineering and Applied Sciences (SEAS) on July 1. I am joining Columbia at an exciting juncture in its history, with SEAS approaching its 150th anniversary and preparing for a period of growth. Like each of you, I will now always be connected to MIT as an alum.

I want to thank you for having trusted me to head our great department for the past five years. I am pleased that these years have been marked by remarkable innovation and growth across all aspects of the department – people, education, research, service, community, and leadership. The intensity and the mutual support of the people of MechE are at the core of what makes MIT truly exceptional and what continues to drive us in new directions. I have been simply astonished by the intellect, creativity, curiosity, drive, passion, and innovation of the undergraduate students, the graduate students, the post docs, the faculty, and the alumni of this department. I look forward to hearing news of the continued frontier efforts in both education and research with our unique MIT signature of *mens et manus*.

Thank you, as always, for your continued support of the Department of Mechanical Engineering.

Sincerely,

Mary C. Boyce

Mary C. Boyce, Ford Professor of Engineering and Department Head

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About MechE

Mechanical engineering was one of the original courses of study offered when classes began at the Massachusetts Institute of Technology in 1865. Today, the Department of Mechanical Engineering (MechE) comprises seven principal research areas:

- **Mechanics: modeling, experimentation, and computation**
- **Design, manufacturing, and product development**
- **Controls, instrumentation, and robotics**
- **Energy science and engineering**
- **Ocean science and engineering**
- **Bioengineering**
- **Nano/micro science and technology**

Each of these disciplines encompasses several laboratories and academic programs that foster modeling, analysis, computation, and experimentation. MechE educational programs remain at the leading edge by providing in-depth instruction in engineering principles and unparalleled opportunities for students to apply their knowledge.

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Innovation and Entrepreneurship: The MechE Way

by Alissa Mallinson

Innovation and creativity are concepts that imbue everything we do in the Department of Mechanical Engineering. They're woven into every lab, every experiment, every faculty member and graduate student rooted here. It's who we are.

But as Professor David Wallace teaches his students, innovation and creativity are not the same thing. Creativity is the seed for innovation, and – despite popular belief – it can be learned, according to Professor Ian Hunter. You must learn to think outside the box, to challenge traditional ways of approaching problems, and to develop a full toolbox of knowledge from which to pull.

"Part of the MIT way is to be very knowledgeable and to be able to compute quickly," says Professor Ian Hunter. "That allows you to analyze things around you and unlock opportunities more rapidly than others who might have to take the time to look things up. I find that students who have these skills become more creative."

"I always like to think about solving a problem in a way that might seem counterintuitive," says Professor Kripa Varanasi, "to potentially create something that you wouldn't think could happen, something that gives you a big jump in the ultimate performance."

If creativity is the seed, then innovation is creativity aptly applied. MechE students receive the knowledge and hands-on experience necessary to transform creativity into innovation, into a product that solves a real problem or fulfills a specific need, and the business acumen to turn innovation into entrepreneurship. As Professor Maria Yang explains, technology is just one way to spur innovation; conversely, many great products are driven by a deep understanding of the human needs of end users. It's important for engineers to recognize the difference between "technology push" and "market pull" and to be flexible enough to adjust their ideas as necessary.

The End (Users) Justify the Means

But why is it important for an engineer to know the market, to understand the end users?

"It doesn't matter if people have a second-grade education, they know more about their lives than I will ever know," says Professor Amos Winter. "It's important to start and finish with the end users because they're the ones who have to say, 'I have this need in my life'; and once it's done, it's the end users who have to say, 'Yes! This meets my need.' They're the ones who matter."

MIT mechanical engineers are taught to understand the entire process of product design from beginning to end – to become better innovators, they need to understand who they are innovating for and know how to work with others to get it done. They are taught through experience to appreciate the importance of each person's role in that process and to partner with them to create a cohesive, effective solution that's not only made well, but on time and on budget too.

"The key competitive battleground now is in the area of innovation," says Wallace. "If you have a fantastic hockey team but you show up at the wrong rink, you lose the tournament. Creativity and vision are the right rink. There are a lot of smart people in the world who are very good at executing the details, but ... in order to be competitive, it is also important to be thinking of the next big idea. To be a technical leader, you have to be able to do both."

Course 2.009 students present their invention at this past fall's presentation ceremony.

The Department's curriculum offers a series of undergraduate and graduate product design courses for this purpose – such as Course 2.00b: Toy Lab; Course 2.007: Introduction to Robotics; Course 2.009: Product Engineering Processes; Course 2.013/4: Engineering Systems Design and Development; and Course 2.739: Product Design and Development – as well as programs that integrate elements of fundamental business and marketing ideas, such as the Leaders for Global Operations (LGO) program in conjunction with the Sloan School of Management.

The MIT Entrepreneurial "Ecosystem"

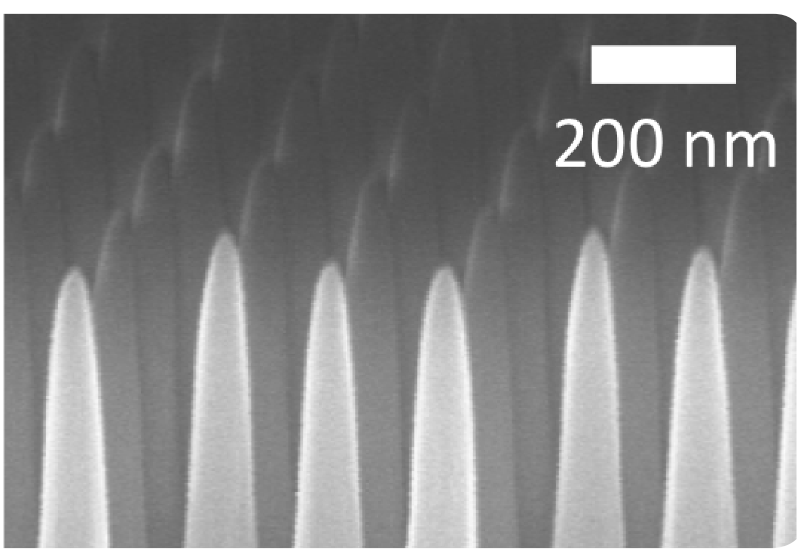
Even so, how could MechE students truly internalize that entrepreneurial drive if MIT as an Institute didn't live it? If our own faculty weren't themselves examples of that renowned MIT entrepreneurial spirit?

It's the fact that MIT lives that spirit that gives it the entrepreneurial ecosystem so coveted by others. Since the beginning, MIT's motto *mens et manus* ("mind and hand") has guided the MIT community toward industry partnerships and entrepreneurship through appreciation for the invention of useful ideas and products. According to a 2011 report by the MIT Martin Trust Center for Entrepreneurship, "if the active companies founded by living MIT alumni formed an independent nation, their revenues would make that nation at least the 17th largest economy in the world."*

The MIT support system is one of the best too — including the MIT Enterprise Forum, the Deshpande Center for Technological Innovation, the Martin Trust Entrepreneurship Center, and a multitude of competitions, such as the $100K Entrepreneurship Competition, the Lemelson-MIT Award, and the IDEAS Challenge, all of which award seed money to help grow promising ideas. Just in the past few years, several MechE students were recognized by all three competitions: Nathan Ball and Nikolai Begg, who each won the Lemelson-MIT Student Prize Award (see pages 14 and 20, respectively), Karina Pikhart and Kevin Cedrone, who each won the MIT IDEAS Challenge (see pages 16 and 29, respectively); and the Varanasi Lab team, which was awarded the Audience Choice Prize at the $100K Entrepreneurship Competition for their product LiquiGlide (see pages 17 and 30).

"Our education here doesn't make a distinction between people who are good at theory and people who are good with their hands, because at MIT, you need to be good at both," says Hunter. "That idea permeates our teaching and has become part of our entrepreneurial culture. As a result, our students are people who march across any discipline to find solutions to problems. And that's very much the MIT way. It's not only important for research, it's also important for successful startups."

MechE faculty are crucial links in this ecosystem of MIT entrepreneurial spirit and know-how. Almost all of them have been part of a commercialization process at one point or another, either by licensing a patent or by directly participating in a startup. In the past 10 years, MechE faculty have licensed more than 200 patents. For many faculty, it's an unparalleled feeling to see their creations utilized for the benefit of the planet and the public.



Graduate students working with Professors Gareth McKinley and George Barbastathis discovered a method of replicating nano cones on glass following a class project in Course 2.71: Optics to create anti-reflective, anti-fogging, self-cleaning glass.

*http://entrepreneurship.mit.edu/impact

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Professor George Barbastathis: Multi-Functional Glass

Professor George Barbastathis is no stranger to cool inventions. A co-inventor of the "Harry Potter"-esque invisibility cloak, Barbastathis's newest development is multi-functional glass that is anti-reflective, anti-fogging, and self-cleaning. First developed by two of his optics students as part of a class project, the anti-reflection idea is based on reducing the mismatch that occurs between the properties of air and glass when they meet, causing light to reflect.

The solution to this mismatch was widely known: nano cones placed at the interface of the two media create a gradual transition that smoothens the mismatch and prevents reflection. But they still needed a high aspect ratio to simultaneously meet two requirements: firstly, a diameter that is smaller than half the wavelength of light to make sure the light does not "see" them but rather propagates through them as though they were an effective medium; and secondly, the most length to ensure a slow transition from air to bulk glass to greatly reduce reflection.

In addition to addressing this mismatch, the nano cone shapes also alter the wetting behavior of glass, making it superhydrophilic (meaning that water droplets do not "bead up" on the surface) or, alternatively, after coating it with a very thin layer of an organic fluoro-chemical, making it superhydrophobic (meaning that water droplets form perfect spherical balls on top of the glass).

Post-doctoral candidate Chih-Hao Chang and graduate student Hyung-ryul "Johnny" Choi created a new process for manufacturing the cones using a shrinking mask of silicon that disappears gradually as it and the glass substrate are etched, thus creating an almost linear slope – a cone shape that is also very slender, with the slope determined by the relative etching speed between the silicon and the glass. Along with student Kyoo-Chul "Kenneth" Park and his advisors Professors Gareth McKinley from MechE and Bob Cohen from ChemE, the team soon demonstrated the multi-functionality conclusively in terms of both anti-reflection and wetting behavior.

"I always like to think about solving a problem in a way that might seem counterintuitive."

-Professor Kripa Varanasi

After graduate student Jeong-gil Kim joined the team, their next step was to replicate the cone shapes by impressing the patterned glass onto a polymer substrate. But they ran into another problem: holes were forming instead of cones. Disappointed at first, they soon realized that the holes were actually even more effective in one important way.

"The cones are very slender," explains Barbastathis, "and one could reasonably ask if they would shatter, and, in some applications, they might. On the other hand, the holes are not only more robust, but – if you can imagine what the negative of a cone looks like in a pattern – they support each other very well too."

As Barbastathis and his team think about licensing their nano pattern to companies, a number of other potential applications have emerged.

"Once we finesse the nano replication process, we should be able to manufacture them for a few pennies per square inch," he says. "We're quite excited and looking forward to the easy replication for use in applications such as photovoltaics, smart phones, and even building windows."

Professor Doug Hart: 3D Scanning and Imaging

Ending with the largest dental company sale in history even before receiving Series B funding, Brontes Technologies, Inc. began with 3D technology born out of particle image velocimetry that created 3D maps of flows using two cameras. That is what Professor Doug Hart was working on when he was asked to speak to a group of Taiwanese opto-electronics researchers working on 3D imaging for computer animation.

"I went out there wondering what a fluid dynamicist was going to talk to an electro optics group about," Hart says. "But at the last second it occurred to me that you could use the same technology we were using for velocimetry to image objects in 3D by simply projecting a speckled pattern onto an object and imaging it with a camera. Two years later, without my knowing, that group submitted a pre-proposal to the Taiwanese government to work with us on the idea."

After a successful collaboration wherein Hart's team developed a system to take human expression and apply it to animated characters, the two groups went their separate ways. Hart was trying to solve the problem of how to improve 3D processing speed without decreasing the accuracy. The less spatial disparity between the two cameras, the better the processing, but as they approached the limit, they wondered what to do next.

"I was sitting in my office asking myself how we could get them any closer when I realized that we could put an off-axis aperture in the system and rotate it," says Hart. "It was like taking 50 cameras and putting them all in one tiny lens, and then being able to dynamically control the imaging."

Professor Doug Hart's dental scanning technology.

They teamed up with the then-newly formed MIT Deshpande Center and entered the MIT $100K Entrepreneurship Competition (then a $50K competition), where they were joined by two MBA students. At the time, Brontes was pitching the system as a facial recognition device, but after a visit to the dentist by a team member, the group changed its mind and decided to develop the technology as a dental scanner instead. What developed as a result was the first video-rate intra-oral dental scanner, which looks like a toothbrush and scans the mouth, replacing the antiquated casting process. It was the right choice, because as they started to search for Series B funding, Brontes received an unexpected bid for purchase. Then a second, higher bid came in from 3M Company, and they decided to sell.

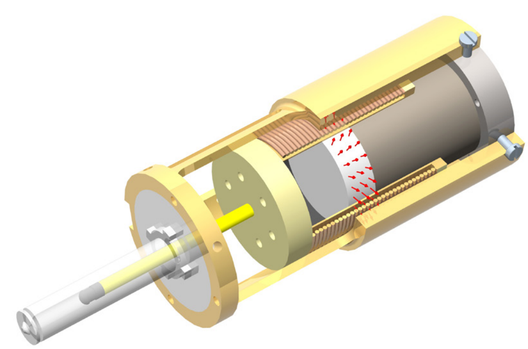
When Hart was approached shortly thereafter about applying the technology to hearing aids, he didn't need much arm-twisting to start another company.

"After we sold Brontes," he says, "I felt like something was missing from my life, because there wasn't this intense excitement and hard work and team building. I had been bitten by the entrepreneurship bug."

The dental scanning technology was too big to fit into ear canals, so Hart created a second 3D system from scratch. The new invention resulted in Lantos Technologies' Lantos Scanner, a portable device that creates perfect-fit hearing aids.

Professor Ian Hunter: Bioinstrumentation

Professor Ian Hunter, director of the MIT BioInstrumentation Lab, is well known for his love of invention and his passion for commercialization. He has founded and/or co-founded 22 companies, the two most recent within the past year. MicroMS and Portal Instruments both spun out of instruments Professor Hunter invented with post docs and students in his lab.



An illustration of Professor Hunter's needleless injector.

MicroMS was developed in conjunction with Dr. Brian Hemond, one of Professor Hunter's PhD students. Together, the two created a miniature mass spectrometer (MS), an instrument for chemical analysis that is usually very large. The portable device they developed is handheld, with a manufacturing cost possibly as low as $100. It can be used to characterize smells, such as wine and coffee; to detect undesired chemicals such as lead or pesticides; or possibly even to deduce one's health status from breath analysis.

"I consider myself primarily to be an inventor, but I'm also a serial entrepreneur," says Professor Hunter. "I enjoy inventing things, and I like to make sure that if I've got an invention that is going to do good for the planet that it gets out there and gets commercialized. Rather than handing it off to somebody, I like to guide it through its initial stages."

Portal Instruments manufactures a jet injector that delivers drugs through the skin without a needle at specific depths and volumes. Following two years of successful feasibility studies, he decided that instead of continuing to adapt the technology to different applications, such as the eye and ear, he was ready to start optimizing it in the context of a startup company. Portal Instruments was incorporated late in 2012 with Dr. Patrick Anquetil (MIT PhD '05, Harvard Business School MBA '09), who Professor Hunter named CEO.

"There are four key philosophical approaches to innovation," says Professor Hunter. "One is to be able to carry a lot of laws and equations around in your head and be able to compute them quickly.

"Two is to surround yourself with great tools so you can implement an idea as soon as possible.

"Three is to surround yourself with people who can criticize what you are doing and keep you on your toes.

"And the last one is to be passionate about what you do. Without that, the other elements are irrelevant."

Professor Yang Shao-Horn: Lithium Air Batteries

It's clear why innovative product design and development are important, but what about innovative fundamental research? Without it, the game-changing discoveries and products you see at the end of the process would never exist.

Take Professor Yang Shao-Horn: Her Electrochemical Energy Lab's (EEL) fundamental research often has a domino effect that leads to a progressive series of discoveries, as is the case with their current research project to develop efficient lithium-air (Li-O2) batteries for electric cars.

Betar Gallant connects a lithium-air battery used for testing by Professor Shao-Horn's EEL lab.

Because Li-O2 batteries utilize oxygen for energy storage instead of the heavier transition metal-based materials in today's batteries, they represent the potential to create a lightweight battery with up to three times the energy density of standard lithium-ion batteries. The inefficient charging process in Li-O2 batteries and the inability to cycle (charge and discharge) more than a few times have posed significant obstacles, but if these challenges can be overcome, electric cars with rechargeable, lightweight batteries could become a consumer-friendly alternative to gasoline-fueled vehicles. With their eyes toward that goal, Shao-Horn and her team – Ethan Crumlin (SB '05, SM '07, PhD '12), now a post-doc at Lawrence Berkeley National Lab; recent graduate Betar Gallant (BS '08, SM '10, PhD '13); and Yi-Chun Lu (PhD '12), now an assistant professor at Chinese University of Hong Kong – made innovative developments that have progressed the fundamental understanding of lithium-air batteries and moved them closer to market.

Shao-Horn's group has pursued a strategy that combines fundamental characterization and electrode materials design to help address the efficiency challenges. In one project, the group developed a vertical carbon-fiber-based electrode, increasing the amount of void space – essential for maximizing the amount of discharge product and energy that can be stored – up to roughly 90% compared with approximately 60% in more conventional electrodes. The electrode structure enabled one of the highest gravimetric energy densities, 2400 Wh/kgelectrode, to be realized to date. The team was pleased to discover that an unintended consequence of this electrode development – where the carbon is arranged in an organized, vertically aligned "carpet" pattern – was the ability to visualize the electrode behavior during charge and discharge and "see" how the discharge product grows and disappears.

In another project, the team was able to watch the electrochemical reactions taking place in real time during discharge and charge using an *in situ* ambient pressure X-ray photoelectron spectroscope (XPS). Their study showed that using an all-solid-state battery with metal oxides as the oxygen electrode is crucial for studying the fundamental chemistry of discharge products and their removal during charge, because carbon-based electrodes can react parasitically during discharge, preventing direct study of the fundamental electrochemistry of lithium peroxide formation and oxidation. Such an approach can provide important insights into the reversibility, round-trip efficiency, and cycle life limitations in real cells. New fundamental insights from this work can be used to drive development of practical electrode materials suitable for use in real cells.

Just this past spring, the team made yet another step in their quest to develop a commercial lithium-air battery: Using a transmission electron microscope, they observed in real time that the oxidation of lithium peroxide at high charging rates occurs closest to the carbon nanotubes used in the electrode rather than at the electrolyte interface. As a result, they now understand that this resistance of lithium peroxide to a flow of electrons is a major contributor to charging limitations at high rates – a critical obstacle for automotive applications where fast charging is a requirement for consumers.

Professor David Wallace: Design Process Education

For many MechE students, particularly those who take the ever-popular Course 2.009: Product Engineering Processes, Professor David Wallace is a hero.

Wallace's fun-loving approach to teaching is a welcome surprise to overworked students who arrive expecting formulas and textbooks. "I'm a big believer in active learning," he explains. "I like to play games and have fun with my students. I want them to be engaged in the lecture and get excited to go do things on their own. If the students see the instructors getting excited about the subject, they tend to get excited too."

Wallace notices if they're not and adjusts his approach, often spending close to 100 hours of development time every year improving the course – just another facet of his innovative teaching philosophy.

"We ask our students to work very hard in this class. So we have to work just as hard," he says. "Every year I choose what I think are the two weakest aspects of the most recent class and try to replace them with one or two new things that will hopefully work better."

2.009 takes students through the entire process of real-world product development, encouraging creativity and unfettered brainstorming, sketching, prototyping, and all the steps in between. When they've completed this capstone course – a requirement for a mechanical engineering undergraduate degree at MIT – they not only have hands-on experience and an understanding of the business considerations, but they also understand what it means to innovate.

"We're really trying to build the attitudes and set of skills that will allow these engineers to become technical innovators in various forms. They brainstorm their own ideas, they develop their own ideas – and we have them do things that are very real. That level of engagement with their own creativity motivates them to go beyond a homework assignment and approach it as if it's a real product. That's when a lot of learning takes place."

An end user tests Professor Winter's Leveraged Freedom Chair.

According to Wallace, almost every year there are a handful of 2.009 teams that file for patents and incorporate, such as 6dot Innovations (braille labeler, see page 16), HelmetHub (helmet vending machine), Phil (intelligent faucet attachment), and Ferno (compact outdoor stove). But, "it's really about education and lighting that fire in the students," he says.

Professor Amos Winter: Products for Developing Countries

Assistant Professor Amos Winter (SM '05, PhD '11) doesn't leave the commercialization of his inventions to chance. With a research focus on product and machine design for developing countries, Winter takes a strategic two-pronged approach to bringing his products to market. Last year, he created Global Research Innovation and Technology (GRIT) to commercialize his Leveraged Freedom Chair (LFC) and serve as an established vehicle for future product commercialization.

"I felt very strongly that I needed to create a mechanism through which I could take the technologies we create in the lab and transfer them into the real world ... without me personally having to expend the effort every time to get them there," says Winter.

He also partners with large, successful companies who have a proven track record in the markets where new research opportunities exist. For Winter, there are three reasons for collaborating with large outside organizations: 1) they have tremendous internal R&D capabilities and can contribute to the research; 2) they have the ability to manufacture at enormous scales; and 3) they know the market well and have established distribution channels. "As engineers, we can contribute knowledge generation and fundamental research that leads to innovative technology, but large companies are good at making it, productizing it, and distributing it. It's a great partnership," he says.

Some designers may consider the restrictive parameters involved in designing products for the developing world a hindrance, but Winter revels in it.

A great example is his LFC. He wanted to create a wheelchair that could travel off-road for approximately 2 miles a day, could be powered manually with ease, was small enough to use indoors, and didn't cost more than $200. It was these constraints that forced Winter to create an innovative solution, one that was able to solve a complicated problem simply and elegantly.

Made out of widely accessible bike parts, his chair exploits basic geometry and eliminates the need for complex mechanisms. By pushing on two levers and adjusting the height of their grip, LFC users vary the torque going into the drive train as needed, based on the environment.

"These types of challenges are extremely difficult to solve, with no clear solution, so we really have to innovate. But there's a potential for huge impact, and you may affect a person in a life or death way. Not only that, but if your solution works in a very constrained environment, then it has the potential to work well everywhere."

Professor Maria Yang: Early-Stage Design

Where other MechE faculty members come bearing specific innovative artifacts, Professor Maria Yang offers conceptual strategies for innovation, regardless of the technology. For her, innovation first manifests itself in early-stage design.

"My pitch is for visual literacy," she explains. "Students come to MIT and they are very strong mathematically, but visual literacy is part and parcel of being a mechanical engineer. You need to think about how things fit together, how gears work, how a product works."

2.00: Introduction to Design students John Thomas ('15), Rene Miller ('15), and Margaret Coad ('15) work on a class project.

To find out how important early-stage sketching is, Professor Yang conducted several studies. "We found that those people who drew earlier in the process tended to have better design outcomes," she says. "But surprisingly, one's sketching ability didn't seem to play a role in how well the design turned out."

"The key competitive battleground now is in the area of innovation."

-Professor David Wallace

Yang describes three major types of drawing for product design: prescriptive (giving instructions for someone else, such as a blueprint), communication (using a drawing to explain or sell an idea), and thinking (creating drawings for oneself to think through an idea), the third being the one she is most interested in, the one she believes begets creativity and innovation.

"'Thinking drawing' tells people how to think for themselves. It doesn't matter how well you draw, it just helps people think through their ideas. It's known as having 'a dialogue with the paper.'"

Based on her studies, Yang encourages her students in 2.00: Introduction to Design to sketch and build prototypes early in the design process. This strategy also extends to the design of complex engineering systems. "Engineers typically think in terms of sub-systems and sub-components," she says, "but integration is a major issue, and one of the things we've found through our work with NASA is how critical visualization is in facilitating integration.

"Understanding the process of designing things – and sketching is a piece of that – helps engineers to see the process end to end."

STE@M

Sports Technology and Education @ MIT

by Alissa Mallinson

If the only thing you saw from the STE@M workshop this past winter were photos of MIT students windsurfing on the sunny shores of Maui, you might have your suspicions as to whether or not it was really an educational trip.

STE@M – Sports Technology and Education @ MIT – was recently started by MechE Professor Anette "Peko" Hosoi for students who are interested in "advancing technology at the interface of sports and engineering."

Indeed, the group's success is rooted in the importance of an immersive experience and the pursuit of one's passions. That is what prompted Hosoi to start STE@M in the first place. She will never forget the first time she went downhill biking – on a cross-country bike.

"After my initial exhilaration, my first thought was, 'I really need a better bike.' My second thought was, 'That would be a great engineering challenge for students who are interested in sports.'"

Mens et Manus

The Maui workshop, inaugurated this past year, has quickly become a hallmark of STE@M. The students – both undergraduates and graduates – receive 6 credits for the course, offered during Intersession Activities Period (IAP). They had multiple assignments to complete pre-Maui, but their first major lesson came almost as soon as they arrived. They spent many hours in Maui waters, windsurfing and kiteboarding, and encountered several functional challenges as a result of diving in and experiencing these activities first hand. Each of the students' final projects was directly inspired by this hands-on immersion.

STE@M students gather around Professors Hosoi and Slocum, and Patagonia's O'Hara, as well as Francisco Goya (holding MIT penant) at Goya Windsurfing.

"We were trying to tie all the pieces together and make it clear that you need to be connected to a domain and its community on some level to be able to innovate in that area," says Hosoi.

Do What You Love

The second lesson they learned was something a bit closer to the heart but equally fundamental: Pursue your passions, and the rest will follow. Guest speakers at the workshop – including windsurfing legend Robby Naish, renowned kiteboard designer Ken Winner, VMWare co-founder and sailor Diane Greene, and windsurfing champion Francisco Goya – were all inspiring examples of finding success in the unwavering pursuit of your interests and dreams. For most students, this idea was the most meaningful lesson of the trip.

According to one of the participating students, "I think I can speak for everyone when I say that this workshop was incredibly valuable to my career development and my development as an engineer. The people we met and the topics we discussed inspire me even more to pursue my passions and make a difference."

Another student said, "I learned a lot about the design process, from keeping a journal, brainstorming, and patenting, to marketing and commercialization. But more importantly, for me, the trip … really exemplified the importance of identifying my interests, following my passions, and turning them into a career. I came back with great confidence that I will succeed just doing the things I love."

Blowing in the Wind

As part of a focus on wind technology and environmental issues, the workshop also included

(continued on page 13)

Alumni Spotlight: Kiva Systems

Benge Ambrogi (SM '87), Pete Mansfield (PhD '90), Mick Mountz (SB '87), Matt Verminski (SM '98), and Pete Wurman (SB '87)

by Alissa Mallinson

When a handful of MIT graduates get together to solve a problem, amazing things can happen – in this case, the most disruptive order fulfillment system to enter the industry in more than a decade.

Kiva Systems founder and CEO Mick Mountz (SB '87) and CTO and technical co-founder Pete Wurman (SB '87) were roommates as MechE undergraduates at MIT and fellow members of the Sigma Alpha Epsilon (SAE) fraternity. Together with technical co-founder Raff D'Andrea, they developed Kiva's revolutionary real-time order fulfillment solution combining robotics and a highly adaptive algorithm-intensive enterprise software application. Soon thereafter, VP of hardware Matthew Verminski (SM '98), VP of product and program management Benge Ambrogi (SM '87) and engineering fellow Pete Mansfield (PhD '90) joined the start-up.

"Kiva Systems isn't an MIT startup company – we created the business about 15 years after graduating – but it's interesting just how involved the MechE and MIT community has been in its success," says Mountz. "I used the MIT network to get everybody I could think of to help us build this product."

The Kiva System – the first version of which was built in 2004 – is a suite of simple yet dynamic robots, complex back-end algorithms, and a touch-screen application that makes the whole system comprehensive and easy to navigate. From the time you submit an online order until 5 minutes later when the order is ready to ship, the Kiva System finds the ordered items and brings them to the pick station.

A Kiva Systems bot.

Before Kiva Systems, order fulfillment was often a long, manual process that could easily prevent a company from becoming profitable. That was exactly the case with Webvan, the company Mountz worked for prior to starting Kiva. Webvan was an Internet grocery delivery startup with a fulfillment rate of about 50 units per hour.

"We were losing money on every order," explains Mountz. "It was my job to study how we were picking orders out of the warehouse and find a way to do it much faster. We got it up to 200 units per hour, but it still wasn't good enough, and unfortunately the company went out of business."

Mountz made it his mission to find a more efficient and productive process for fulfillment.

"We set out to build a system that could do 600 units per hour," he continues. "The problem was clear: We needed to get 'red,' 'green,' and 'blue' in the box. We started brainstorming from a blank sheet and asking ourselves very basic, almost silly questions. 'Why aren't the units already in the box? Why didn't the vendor just ship them that way? Why don't the products just get in the box themselves?' We didn't constrain ourselves to traditional approaches or ways of thinking.

"At one point we asked ourselves, 'What if the products walked by themselves?' It was a funny thought, but what if?"

In the end, Kiva's solution, which can produce 600 units per hour, does indeed enable products to "walk" to the boxes themselves.

Here's how it works. A warehouse employee logs into the pick station through a touch screen. The customer order arrives in real time, and robots immediately begin moving toward a storage pod that contains the item. A navigation system on the warehouse floor consists of a series of stickers, which the robots take photos of along the way to keep them on a consistent path. Once the robot arrives at the pick station with a pod that contains the ordered item, a laser points to the individual cubby holding the item. The pick-worker takes it out, scans it, and places it into a tote for shipping. After the robot has delivered its cargo, it takes the pod to a new dynamic location in the warehouse where it awaits its next mission.

"Almost all our customers buy our system on a 2-year or better return," says Mountz. "That means that the workforce in a Kiva building is doing two to four as many orders per hour compared to their old way."

All that and yet the Kiva System is incredibly simple, at least from the outside. The robot consists of thermoformed shells with sensors, injection-molded parts, cabling and harnessing, castings, motors, actuators, and gear boxes. The electronics bring it all together with embedded firmware and control systems. On the back end, software is engineered to distribute missions to the robots about what to fetch, from where, where to bring it, and how to get it there most efficiently.

Verminski says, "We try to keep the robots very simple. They move forward, pick things up, travel, and traverse, but they have to do it on a very consistent, reliable basis. From a mechanical perspective, it's a playground, because there are a vast array of technologies going into it that have to come together seamlessly to form an electromechanical system."

"I love its simplicity," adds Mountz. "Companies come to us with hundreds of mechanical contraptions they have in their current buildings. In these types of warehouses, you have to keep spare parts in the back room for all the different contraptions. If something goes down, the whole building stops working. With our solution, if you put 100 robots out there and any one of them dies, the other 99 keep running. It's this idea that we simplified it down to a robot and some software, and with that we can design and build almost any warehouse solution."

(STE@M, cont. from page 11)

stops at several local companies and organizations, including Auwahi Wind, the Office of the Mayor of Maui, Naish, and Goya Windsurfing. Students learned about the energy issues Maui is facing and some of the solutions under consideration. They also attended design sessions led by Professor Alexander Slocum and participated in business case discussions led by Tetsuya O'Hara, director of R&D at Patagonia and STE@M advisory board member. O'Hara taught the students how to analyze their ideas using environmental analysis, SWOT (strengths, weaknesses, opportunities, threats) analysis, and five force analysis.

The Goal is to Teach

Back in the states, each team of students presented a sports technology idea that represented all the phases of idea generation and analysis they had learned throughout the week-long workshop. Their ideas clearly emanated from their experience in the field – better ways of relaxing on the ocean, fun games to play in the water, kites that fly in low winds, and more efficient and comfortable gear – and converged with their technical knowledge and experience.

Although pursuit of their idea past their final presentation was optional, several undergraduate students are developing them further for their theses, and a few teams are even moving on to the proof-of-concept and prototyping phases. According to Hosoi, those innovations, if manufactured, will likely be licensed to some of the companies that work with STE@M. As a thank you for their hospitality, host companies also receive introductions to some of MIT's students and faculty members who might be interested in forming partnerships.

"At MIT, we're in the business of educating. And for the companies that were so accommodating to us and opened their doors to our students, we would like to give something back," says Hosoi. "We want companies to know that MIT students are working to advance sports technology and that we're doing exciting, innovative work. Our ultimate goal is to give the students opportunities that they wouldn't otherwise have."

Alumni Spotlight: Atlas Devices

Nate Ball (SB '05, SM '07) and Bryan Schmid (SB '03, SM '05)

MechE alumni Nate Ball (SB '05, SM '07) and Bryan Schmid (SB '03, SM '05) entered the MIT Institute for Soldier Nanotechnologies' (ISN) annual Soldier Design Competition in 2005 with fellow MechE alumni Daniel Walker (SB '05, SM '09) and Tim Fofonoff (SM '03, PhD '08). The competition challenges participants to solve the real-life problems of active soldiers. The group chose to address the need to easily and quickly descend and ascend during rescue missions. Although their solution did not win the competition, their idea – the Atlas Power Ascender (APA) – became the basis for startup Atlas Devices and a life-saving tool for soldiers, firemen, and policemen throughout the world.

How did you come upon this specific solution?

It certainly wasn't our first idea. There have been many iterations. We wanted to focus on a solution that was intuitive to the user, inspired by a power tool, and integrated into common climbing equipment that most people would be familiar with. We kept those design parameters, applied high-powered batteries and power-dense motors, and just let her rip.

What improvements did the APA feature over the then-current equipment?

Comparing it to standard climbing or rescue equipment, which uses similar techniques but doesn't have the power

Bryan Schmid

Nate Ball

ascender attached to it, we can perform the same tasks anywhere from 10 to 20 times faster. It takes no effort because you're just squeezing a trigger as opposed to exerting the huge physical effort that climbing and conventional rescues require. A conventional high-angle rescue normally involves five to 10 rescuers over the course of hours, whereas a rescue conducted with an APA involves only one or two rescuers and is completed in a fraction of the time.

How does the APA work?

The system has a trigger that acts like a throttle for the electromechanical drive train and a control interface that's very similar to a standard power tool, with a hand grip and direction control switches. The user wraps the rope through the system, and the ascender acts almost like an elevator along the rope, climbing up and down it instead of spooling it up as it moves like a conventional winch might do. Once the rope is in, you connect it to your harness or rigging point, pull the trigger, and off you go. You can go up and down with this system by just selecting the direction and then commanding the speed. The ascender is about 22 pounds including its battery (which is separable) and can lift up to 600 pounds.

What kind of engineering challenges did you encounter in your design?

When you try to design a system as small as our APA that can lift 600 pounds at the rate it does, there are a lot of challenges. One of the hardest things we've always faced is how to grab onto the rope and climb it efficiently across the whole load range we want to be able to lift. Then there are the usual challenges of keeping the efficiency high through the drive train as we pull power out of the battery and deliver it to the rope-climbing mechanism. We do a pretty good job of that, but we're still pulling so much power through the system that even at high efficiencies we have a lot of watts of heat to remove, so heat transfer becomes a bigger issue. On top of that, we need it to be rugged for mountainous use and submersible for maritime applications. Meeting those needs without compromising the size and lightweight portability is incredibly challenging.

Much of the early work went into the rope-climbing mechanisms, and that's where most of our company's IP is held. Many other benefits of the ascender, such as its small size and low weight, have come from a very high level of integration. Almost every part of the system is serving multiple functions. Designing the ascender usually feels like trying to solve those sliding block puzzles, but in multiple dimensions.

Did all these limitations make it difficult to innovate?

No, they absolutely forced it. There's never been a set of off-the-shelf components that allows us to meet all those specifications, so it's required us to develop our own technology.

What fueled your decision to commercialize?

The ISN was very involved in our commercialization. There are a lot of military decision-makers that walk through the Soldier Design Competition to review the projects, so military interest following the competition is high. About a year after we entered, we got our first order from the Army's Rapid Equipping Force (REF), whose purpose is to rapidly transition new technologies that soldiers in the field are requesting. The interest and feedback we received from our first customers motivated us to commercialize the product.

To date, we've been heavily focused on the needs of the military market. The military performs many types of vertical operations every day, whether it's in maritime environments where you might want to board a large ship from a small craft or airborne operations where the APA can serve as a backup hoist or even convert any non-rescue-specific helicopter into an extraction-capable solution. There are other markets where the Ascender can be useful too, such as in the commercial sector, where industrial access is often an issue. In fact, one of our earliest sales was actually to MIT for that purpose: the Department of Athletics, Physical Education, and Recreation (DAPER) bought a specialized 2-axis unit to access the scoreboard that's out over the pool.

How difficult was the transition from engineering to entrepreneurship?

MIT certainly fosters an interest in entrepreneurship and shows the students that it's a career option many people find very fulfilling. It's a different challenge, but it uses a lot of the same skills we learn as engineers, such as the way you break

Military airborne operations are aided by Atlas Device's Atlas Power Ascender.

down a problem and attack it. We also received some crucial help from the MIT Venture Mentoring Service during our formative years. Because of MIT's strong entrepreneurial community, we always felt well supported and still do to this day. We enjoy the opportunity to support other entrepreneurs in return.

Nate Ball is the chief technical officer at Atlas Devices and Bryan Schmid is the president.

Alumni Spotlight: 6dot Innovations

Karina Pikhart (SB '09)

by Alissa Mallinson

The beginnings of 6dot Innovations, an assistive technology company started by MechE alumna Karina Pikhart (SB '09), take us back to the fall 2008 offering of Professor David Wallace's popular course 2.009: Product Engineering Processes.

Pikhart was on a 15-member team preparing for the highly anticipated end-of-semester presentation ceremony.

That year, the 2.009 project theme was "products for the home." Like all 2.009 teams, Pikhart's was split into two groups that competed with each other to develop the most promising prototype for their group. Pikhart recalls that her team's final product, the Braille Labeler, was a third idea, replacing the other two when the team's reaction to both of them were lackluster.

"As team leader," says Pikhart, "I saw a spark in the team as we were discussing the labeler idea. So we took a huge leap of faith and decided to move forward with it, scrapping all the work we had done to that point. We were far behind all the other 2.009 teams because of it, but it turned out to be the best decision we could have made."

After graduation, a handful of students from her original 2.009 team continued to work on the labeler, with Pikhart at the helm. But later she moved to the San Francisco Bay area and eventually became the only remaining member to work on the project. While earning a master's degree in mechanical engineering from Stanford University, she decided to make her work on the Braille Labeler official and started 6dot Innovations. A year later, she recruited Robert Liebert, a graduate from Duke University with degrees in engineering and management, to join her.

The Braille Labeler – which won the Aleksander and Anna Anita Leyfell Health Innovation Award at the MIT IDEAS Global Challenge in 2009, as well as several other awards along the way, including a de Florez Competition award – is a handheld product that allows blind children and adults to print custom adhesive labels in Braille for a myriad of items, such as bottled condiments (salad dressing, mustard, chocolate syrup), appliances (microwave, washing machine), and file folders. The ergonomic and lightweight labeler offers several features that set it apart from other Braille labelers, including built-in cutting, responsive buttons, portability, a simple design, and music and math symbols. It prompted the founder and CEO of assistive technology company ProxTalker, Glen Dobbs, to call it "the only Braille labeler I've seen that can do what a Braille labeler should do."

Dobbs was so impressed that last fall his company ProxTalker acquired 6dot, and hired Pikhart and Liebert as senior product development team members. The original plan was to license the labeler to ProxTalker, but, says Pikhart, "after a long series of conversations, we realized we could work really well as a team and build a future together."

Based in Connecticut, ProxTalker was founded four years ago by Dobbs after he designed a product

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Alumni Spotlight: LiquiGlide

Dave Smith (SM '11)

Everyone has probably heard of LiquiGlide by now. Almost every media channel has reported on the company's star product or published the now recognizable photo of ketchup easily sliding out of its downturned bottle, leaving a completely empty container behind. But how much have you heard about the company itself, for whom the innovative condiment bottle coating is just the beginning? *MechE Connects* had a chance to sit down with Dave Smith (SM '11), LiquiGlide's co-inventor and CEO, to discuss more than just the hype.

Where did the idea for LiquiGlide originate?

I'm motivated by different applications for reducing adhesion. My master's research thesis with Professor Kripa Varanasi was on preventing clogs in oil and gas lines created by these big ice-like structures. So looking at different technologies for reducing adhesion made me very well aware of various adhesion problems. At the Varanasi Lab, we were always thinking about low-adhesion non-wetting surfaces. Seeing the success the technology could have in oil and gas lines, we thought it would be interesting to apply it to condiment bottles to prevent adhesion, using materials that are safe enough to eat.

How does it work?

Liquid-impregnated surfaces are comprised of two parts: the porous solid coating that is roughened or has patterned textures, and a liquid that fills up the voids between the features, or fills up the pores of the surface. It's that liquid that gives it the slipperiness. So it is a lot like using oil in a frying pan, but in this case we made that oil layer permanent by trapping it in place by capillary forces. It is a platform technology, so you can use a lot of different materials. The fundamental science was published in a paper we wrote six months ago. In it, we talked about all of the different possible states you could end up in. That state depends upon your choice of solid and liquid materials and the properties of the material in shedding opposites. So for every material you want to shed off, you need to choose a solid and a liquid with different properties. That is a great thing, because you can get this effect from all kinds of different materials, you just need to put them together in different combinations. Much of the success depends on finding the best combinations of liquids and solids.

What makes it innovative and unique?

What's really innovative is the fundamental science we discovered that allows you to make liquid-impregnated surfaces slippery. Certainly, trapping a liquid in a porous surface isn't a new idea. In fact, we can see that by putting a piece of paper in water; it soaks up water and you have a liquid-impregnated surface – which is not necessarily going to be slippery. So it really took an in-depth dive into physical chemistry and fluid mechanics to recognize which chemical properties the solid and liquid need to have. We asked questions about the rheological properties the liquid had to have in order to create the slippery effect. No one had ever done that before, and that is why we have never seen this effect before.

Do you have pre-established criteria of what you're looking for with different combinations?

Yes, that is right. We have an algorithm for selecting solid and liquid materials, and that algorithm is a function of the properties of the material that you want to shed off the surface.

What's LiquiGlide's business plan moving forward?

We have just started our first development project, and we are going to be developing several new projects this year with different companies – largely consumer-packaged goods companies (CPGs) – but there is no limit to LiquiGlide's potential. It can be applied to many different industries, from unclogging processing lines to cooling power plants to de-icing planes. We're also looking at other industries as well. As I mentioned, every product requires a certain set of materials. We always start off by developing a coating, which involves selecting materials that not only create a stable slippery impregnated surface but also satisfy the other requirements the particular application might have. Is it food safe? Is it FDA approved? Is it immiscible enough to give you a shelf life of two years? Every application has its own specific requirements we have to meet.

(6dot, cont. from page 16)

that enabled his autistic son Logan, who is unable to speak, a means for verbal communication using RFID technology. He then took that same RFID technology and developed a product called the Braille Coach, which can be thought of as talking flashcards for teaching Braille.

"Braille education is a really big problem," explains Pikhart. "We observed that very early on in the development of the Braille Labeler. Only 10% of blind children are learning Braille, and about 70% of the blind are unemployed. But of the 10% who are employed, almost all of them know Braille, so there's a huge correlation between Braille literacy and employment."

Finally able to trade in her collection of hats for just one, Pikhart's future is bright: She is now a vice president at ProxTalker, focusing on idea generation and product development.

"The spaces we're working in now, called blind/low vision (B/LV) and augmentative and alternative communication (AAC), are exciting areas with a lot of opportunity for innovation. We have an amazing CEO, a real visionary, so ... the sky is the limit in terms of where the business will go next.

"For me personally, it's a dream come true."

Alumni Spotlight

Kevin Rustagi (SB '11)

By Alissa Mallinson

Recent MechE graduate Kevin Rustagi (SB '11) is a serial entrepreneur. Well, perhaps not quite yet, but he will be. His eyes light up when he talks about interesting ideas and starting companies, and the enthusiasm in his voice is almost palpable.

"I've always been excited about the idea of creating your own company," says Rustagi. "An organization is the ultimate tool. If you want to create a prototype, you've got a hammer, nails, a laser cutter; but if you've got an organization, you can do all kinds of things."

From the time he arrived at MIT in 2007 as a freshman, Rustagi threw himself into project after project, from starting the MIT live music club and leading a clock-making class for undergrads to creating his own industrial laser-etched business cards and co-founding a sweat-free shirt-making business with a fellow student.

But then, one of the reasons he came to MIT was because of its renowned entrepreneurial network, the iconic culture of MIT startups.

"The thing that I love about MIT is that people will meet with you one-on-one and support your idea, especially when it's at a very early stage," says Rustagi. "Whether it's alumni like Zipcar founder Robin Chase and her husband Roy Russel, MechE administrators like Brandy Baker, or MechE faculty like Sanjay Sarma and Maria Yang, the fact that people are always willing to meet with you and support you at whatever stage you're at in the entrepreneurial process is phenomenal. It's an important part of the process of understanding who you are as an entrepreneur."

Rustagi's first entrepreneurial project was manufacturing metal and Plexiglas business cards. A participant in the Undergraduate Practice Opportunities Program (UPOP) during his sophomore year, he had an unexpected bout of frostbite that caused him to sign up late and miss out on receiving the standard UPOP business cards. So he decided to make his own. "I wanted to make something cool, so I found some fluorescent Plexiglas and started cranking out laser-cut and laser-etched business cards. I took them to the UPOP Career Fair later that week, and they really stood out."

He made some cards for friends, and then sold some of them too. "That was the most phenomenal feeling," he remembers. "I'd built some things before, but I'd never had anyone pay me for something I had made. It was extremely addictive."

The same criteria that attracted Rustagi to the idea of non-paper business cards attracted him to his fellow classmate's idea for temperature-regulated shirts. "I remember thinking that the idea was so outlandish, but also very intriguing. I thought that business professionals could definitely be interested." Ministry of Supply, the name of the company that Rustagi eventually started with MIT student Gihan Amarasiriwardena, makes sweat-free, wrinkle-free dress shirts using phase-change materials that pull body heat from the wearer when it's warm out and releases that heat back to the wearer when the temperature cools down. With early funding and initial product sold, Rustagi hired Sloan MBA students Kit Hickey and Aman Advani to help build Ministry of Supply. The company has been very successful in its original round of pre-orders through crowd-sourcing entity Kickstarter, raising almost $400,000 more than its initial $30,000 goal.

Rustagi explains that his two major criteria for identifying a worthy idea are novelty and usefulness.

"Once I have that initial concept, I try to do a lot of back and forth with many different people. Their feedback allows me to shape the idea. It has to be exciting and people have to want it. If they get excited, then I think there could be something there."

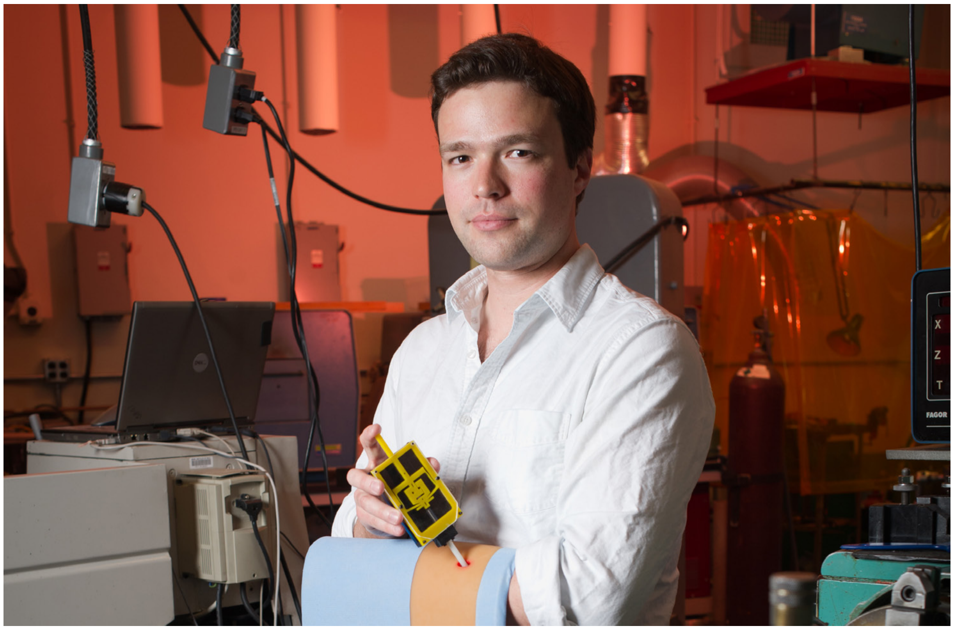
Rustagi's next entrepreneurial space is the intersection of consumer products and audio devices.

"My current project, Invention of Noise, is a music studio that doubles as a product design studio to develop audio devices and consumer products. I have been fortunate enough to be admitted to Stanford's MBA program for the fall of 2014 and hope to arrive ready to start up a new audio-based consumer product company."

Student Spotlight: Nikolai Begg

2013 Lemelson-MIT Student Prize Winner

By Stephanie Martinovich, Lemelson-MIT Program



PhD candidate Nikolai Begg (SM '11) grew up in a box of LEGO® bricks and hasn't stopped tinkering since. Today he is an accomplished inventor with a portfolio of novel medical devices and is a recipient of the prestigious 2013 $30,000 Lemelson-MIT Student Prize for his inventions that make surgical procedures less invasive.

Begg first became interested in medical device engineering during junior high school after studying surgical robots and realizing their profound impact on human health. Today he works with doctors and nurses across medical disciplines in hospitals throughout Boston to better understand how he can have a positive influence on medicine.

"Nikolai has a true appreciation for the importance of living a problem," says Professor Alexander Slocum, Begg's advisor. "In a field where the end user is often difficult to reach, Nikolai is frequently invited into operating rooms after exciting a passion in physicians who can see that he is motivated only by the opportunity to create something that will transform the way they work."

A New "Gold Standard" of Safety in Surgical Procedures

Epidurals, intravenous catheter placements, and bone marrow biopsies are all examples of "puncture access procedures" in which a sharply pointed instrument, the puncture device, is used to create a pathway into the patient's body. Despite puncture access being the first step in many minimally invasive procedures like laparoscopic surgeries, existing devices often plunge forward after breaking through tissue until the surgeon can react and stop applying force, posing a risk to any underlying organs.

Begg invented a puncture access mechanism with a blade that retracts at the moment it passes completely through skin tissue, after years of observing laparoscopic surgeries first-hand. A "force-sensing" instrument, the tip withdraws within 1/100 of a second. The mechanism, which is purely mechanical in nature with only a few parts, is scalable for use in nearly any medical puncture device. Begg also learned that in right kidney laparoscopic procedures, an additional incision has to be made to hold the liver and clear a direct pathway to the kidney. This additional step risks over-puncture, infection, and pain. He developed an incision-less laparoscopic retractor to address this challenge. Inserted through an existing incision, a suture stored within the device is passed out of the body and tensioned to move the organ out of the operating field.

An Ambassador for Invention

Begg's personal passion for invention is just as important as working to inspire the same in others. He has used his knack for explaining complex technologies

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Student Spotlight: Paul Lazarescu

A Modern-Day Inventor

By Jessica Fujimara, MIT News Office

As a child, Paul Lazarescu (SB '13) dreamed of becoming an inventor.

"I always loved building things," he says. "For my birthday presents, I'd get remote-control cars and kits, and I once tried to make myself a hovering magnetic car — it didn't work," he chuckles.

Now a recent MechE graduate, Lazarescu is on the way to achieving his childhood dream: He's designed a hand exerciser for stroke rehabilitation, a wheelchair attachment for off-road travel, and a structure for mounting NASA sensors on airplanes.

When he's not busy with classes and internships, Lazarescu spends time with his fraternity brothers in Alpha Epsilon Pi, where he recently finished a term as vice president, or practicing one of his many hobbies: juggling, blacksmithing, scuba diving, playing the guitar, breakdancing, and krav maga, an Israeli system of self-defense. "I love learning new things and picking up random talents here and there," Lazarescu says.

Wheels Turning

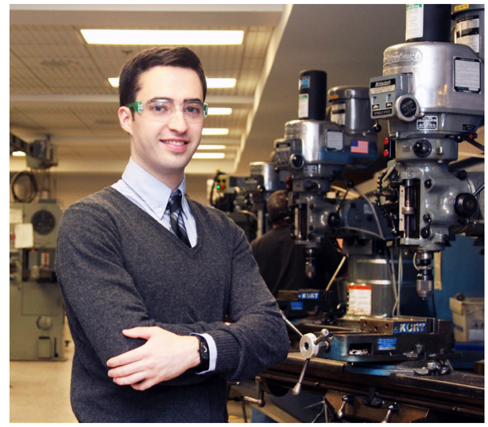
One pastime Lazarescu never thought he'd try was wheelchair basketball. But the summer after his sophomore year, he found himself in a small town in Guatemala, huffing from one side of the court to the other.

Lazarescu and current MechE undergraduate Rachel Dias Carlson had received funding from the MIT Public Service Center for travel to Antigua, Guatemala, to work on low-cost, rugged wheelchair designs.

Lazarescu worked on a large wheel that attaches to the front of a wheelchair. "It's like a little bike tire; you can go on gravel and everything that the little wheels wouldn't be able to deal with," he says. In the United States, such an attachment costs around $500, far out of reach for poorer populations in Guatemala. "In the end, we made something that could be produced and sold for $50," Lazarescu says.

Later that summer, he worked at the University of California at Irvine, where he helped design a device that employs a spinning wheel to help stroke victims recover their ability to grip with their hands.

"Many people who have had strokes have issues opening their hands and other things that we take for granted, like holding a pencil or picking up keys," Lazarescu explains. The wheel on his device connects to a handgrip, and the spinning of the wheel opens and closes the grip. A patient holding the handgrip could then practice timing the opening and closing of his or her hand to match the spinning of the wheel.



Sensors in the Sky

The following January, Lazarescu's attention shifted from the ground to the air. As an intern at NASA's Goddard Space Flight Center, he worked on designs for attaching two microwave radiation sensors to an airplane that would fly over ocean and land to measure salinity and water content, respectively. The data from the sensors would then be used to calibrate a similar sensor on a satellite currently in orbit.

Although he loves engineering, Lazarescu has also nurtured an interest in business during his time in MechE, founding an investing club his junior year. This summer, he is starting as a business analyst at consulting firm McKinsey & Company. One day, Lazarescu hopes to create his own startup, "an engineering, cutting-edge company that makes a big impact through inventions and innovation," he says.

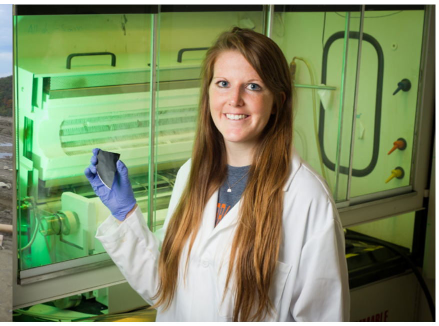
Watch a video of his hand exerciser at http://youtu.be/AaaCkv8jgcI or read the original MIT News Office article at http://bit.ly/16XYbnS.

Student Spotlight

Melinda Hale (PhD '13) and Allison Yost (SM '12)

By Alissa Mallinson

Melinda Hale



Allison Yost

Entrepreneurs abound in MechE, but they couldn't do it without the MIT entrepreneurial community, comprising an army of faculty, students, and staff ready to help at any stage.

Recent MechE graduate Melinda Hale (PhD '13) is one of them. For three years, she has been an organizer of the MIT Global Startup Workshop, which began as part of the MIT $100K Entrepreneurship Competition to teach other universities how to run a business plan competition. Now, it's an international conference held in a different country each year to teach and encourage entrepreneurship. This past year, Hale was one of two lead organizers of the event.

"There are other entrepreneurship-focused conferences held in the US, but very few are so heavily international," she says. "Hearing so many people from different countries talk about their ventures over the years has been a great learning experience for me. There is no way I would have been exposed to such a magnitude of ideas had I not been involved in helping other people start their companies."

When Hale had her own idea for a business this past year, she was ready. What began as consulting for a landfill owner that was looking to maximize its methane collection turned into a startup that sells sensor packages to optimize the vacuum power for removing methane. All landfills must collect the methane that is released into the atmosphere from decomposing trash, but there is an optimum vacuum point to avoid pulling too hard. Hale's sensor technology identifies and maintains that point.

Along with two partners she met through the MIT Martin Trust Center for Entrepreneurship, Hale is dedicating her summer to testing her system and proving that it improves methane yield over the current process.

MechE PhD candidate Allison Yost (SM '12) is also on a mission to help other MIT students become successful entrepreneurs. This past year she was the managing director of the $100K Competition and an organizer of the Trust Center's H@cking Medicine, an initiative that promotes and encourages entrepreneurship in medicine and health care. One major element of the program is the hack-a-thon, a weekend retreat in which students, clinicians, entrepreneurs, MBAs, and designers come together to hack innovative ideas to problems in health care. While the goal isn't to spin out companies, says Yost, several startups have come out of the program.

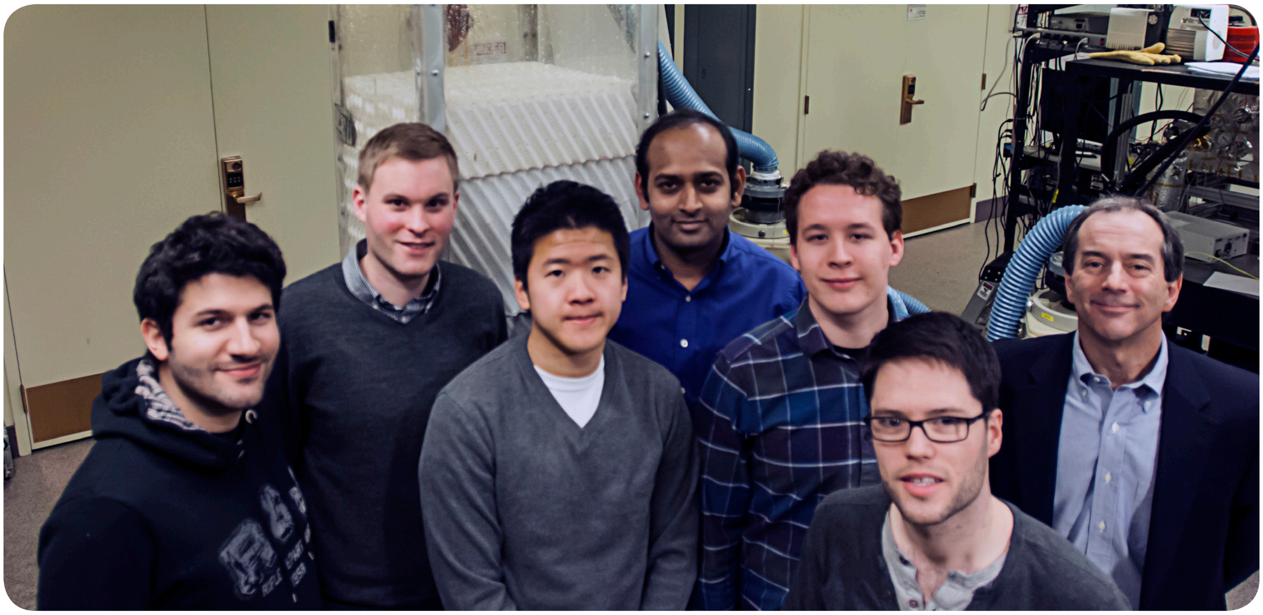
"The goal of H@cking Medicine is to inspire creative thinkers who wouldn't necessarily think to innovate in health care," she explains. "To make any sort of change there, we have to apply new ways of thinking. People often see health care reform as a slow, bureaucratic process, but our goal is to short circuit that process with game-changing technologies."

This spring, Yost was awarded a Patrick J. McGovern Jr. '59 Entrepreneurship Award at the MIT Awards Convocation for her work with H@cking Medicine. She will take over leadership of the hack-a-thon this coming fall.

Faculty Research: Professor John Lienhard

Efficiency Innovation for Water Purification

By Alissa Mallinson



From left to right: Karim Chehayeb, Gregory Thiel, Steven Lam, Prakash Narayan Govindan, Max St. John, Ronan McGovern, and Professor John Lienhard.

If you live in a First World country, you probably do not worry about safe drinking water for you and your family. But according to Professor John H. Lienhard V, the Samuel C. Collins Professor of Mechanical Engineering, you should.

"The world supply of renewable fresh water is fixed by the natural cycle of precipitation and evaporation in the atmosphere," he says. "That supply doesn't grow with the population, so as the world population increases, it's got to be spread among more people. In areas of the world that are more Westernized, the intensity of water usage tends to go up, creating additional demand. The increasing water scarcity worldwide is a much bigger issue than most Americans are aware of."

Lienhard directs a collaboration with King Fahd University of Petroleum and Minerals (KFUPM) and leads the Center for Clean Water and Clean Energy at MIT; he also spearheaded a one-of-a-kind course in desalination as part of the Department of Mechanical Engineering curriculum. He has dedicated the past six years of his career to addressing this worldwide water problem through education and research.

"Most big cities are coastal," he says, "and are sitting next to a lot of undrinkable water. We're looking to take a fixed supply of renewable fresh water and expand it by converting undrinkable water to usable water."

To do this, Lienhard and his team of graduate students and post-docs, including his former post-doc Prakash Narayan, utilize the tools and principles of thermodynamics – such as energy recovery and minimization of entropy generation – to identify the most energy-efficient water purification processes. The group's major focus is a technique called humidification dehumidification (HDH) desalination, an engineered version of the natural rain cycle in which brackish water is heated, evaporated, cooled, and condensed, leaving only purified water at the end of cycle. They have conducted many years of efficiency testing to get to their current level of understanding of the HDH cycle and all the engineering variables that can make it more or less efficient.

"We've asked and answered many questions about efficiency over the past few years," says Lienhard, "such as whether to heat the water or the air, whether to use a closed loop water system or a closed loop air system or both, whether to extract some of the air from the humidifier and inject it into the dehumidifier to achieve better performance." They have also looked at several potential components, such as solar air heaters.

All these years of testing have led them to a very promising solution, one that optimizes the dehumidification component to arrive at the most efficient system.

"The dehumidifier is one of the most awkward components of the HDH system from an engineering perspective," says Lienhard. "It has moist air on one side and a liquid coolant on the other. But moist air doesn't transfer heat and moisture efficiently, so you need a lot of surface area, which adds unwanted weight and cost."

Lienhard's group has developed an innovative solution to this cumbersome problem: a bubbler in place of the classic plate. It is a multi-stage design that eliminates all the metal fins and surface area, replacing them with freshly formed bubbles that do not have as much resistance to heat and mass transfer as steady evaporation on a plate. It works by bubbling moist air into cold water so that the moisture condenses into the cold water.

"The solution we chose is simple, robust, and inexpensive. And because of its simplicity, it will be ideal for deployment in situations where you don't have an engineer on site to keep an eye on the system," says Lienhard.

This technology is intended for use in developing countries where potable water is not easy to come by, but there are also applications in the oil and gas industry involving hypersaline water. Since desalination costs for this technology are the same regardless of the level of salinity, the Lienhard team's highly efficient desalination device is in an ideal position to lead the pack.

"It wasn't the first problem we were working on," says Lienhard, "but we think this technology will work very well in remediating water produced during natural gas extraction by hydraulic fracturing. This water is being pulled through ground formations and, as a result, picks up very high levels of dissolved salts and can be up to five times more saline than seawater."

Lienhard and Narayan, along with their coworkers, have patented their technology; Narayan and other former students have recently formed a company and will begin manufacturing HDH systems this year. The group recently won the Water Technology Idol of the Year Award for their innovation.

For more information, watch a video at http://ilp.mit.edu/videodetail.jsp?id=692

(Begg, cont. from page 20)

to serve as an active mentor throughout his time in MechE. As a graduate instructor Begg helps undergraduate students design, prototype, and refine novel devices to meet the needs of medical practitioners. He also worked with high school students at an MIT-sponsored summer design course to invent and build functional prototypes of devices to introduce exercise into the workplace.

"I believe in showing others that invention does not mean being smart enough to get it right the first time," Begg says. "Creativity is powered by a willingness to learn and take risks."

Bringing a New Face to Invention

"Nikolai Begg exemplifies the modern inventor," says Joshua Schuler, executive director of the Lemelson-MIT Program. "Far from the image of a white-coat scientist at the lab bench, he follows his innate interests, immersing himself in them and collaborating with others to uncover opportunities to invent in every experience. By giving a fresh face to invention, he is inspiring others, including those who may not have ever imagined or believed themselves to be inventors before."

Watch the video at http://techtv.mit.edu/videos/23011-2013-30-000-lemelson-mit-student-prize-winner

Faculty Awards

Harry Asada

Professor Harry Asada was recently named a holder of the Singapore Research Chair.

George Barbastathis

Professor George Barbastathis was recently named a holder of the Singapore Research Chair.

John Brisson

Professor John Brisson was recently named director of the MIT/SUTD Collaboration Office.

Cullen Buie

Assistant Professor Cullen Buie has been selected as one of 14 young research professors to receive the 2013 DuPont Young Professor Award.

Gang Chen

Professor Gang Chen has been selected to receive the Medal of the ASME Heat Transfer Division. He was also recently named a Fellow of the American Physical Society.

Martin Culpepper

Professor Martin Culpepper was recently named a Fellow of the American Society of Mechanical Engineers.

Steven Dubowsky

Professor Steven Dubowsky has been awarded the ASME Mechanism and Robotics Award.

Nicolas Fang

Associate Professor Nick Fang has recently been awarded the 2013 Chao and Trigger Young Manufacturing Engineer Award by the ASME Division of Manufacturing.

John Hart

Associate Professor John Hart was recently named a holder of the Mitsui Career Development Chair.

Anette "Peko" Hosoi

Professor Peko Hosoi was recently named a Fellow of the American Physical Society.

Franz Hover

Professor Franz Hover was recently awarded the Marine Technology Society's Lockheed Martin Award in Ocean Science and Engineering. He was also awarded the 2013 Ruth and Joel Spira Award for Distinguished Teaching.

Ken Kamrin

Assistant Professor Ken Kamrin was recently awarded a National Science Foundation CAREER Award for his proposal titled "Predicting Granular Flows: Amorphous Continuum Modeling with a Length-Scale."

Sangbae Kim

Assistant Professor Sangbae Kim was recently awarded a DARPA Young Investigator Award for his proposal "A Disaster Response Robot Capable of Power Manipulation."

Alexie Kolpak

Assistant Professor Alexie Kolpak was recently named a holder of the Rockwell International Career Development Chair.

John Lienhard

Professor John Lienhard and his former post doc Prakash Narayan, along with their team, were recently awarded the Water Technology Idol of the Year Award at the 2013 Global Water Summit for their humidification-dehumidification-desalination process for cleaning water.

Seth Lloyd

Professor Seth Lloyd received the Quantum Communication Award for Theoretical Research at the 11th International Conference on Quantum Communication, Measurement, and Computing (QCMC 2012).

Gareth McKinley

Professor Gareth McKinley was awarded the Bingham Medal by the Society of Rheology.

Anthony Patera

Professor Anthony Patera was named an honorary member of the Societe de Mathématiques Appliquées et Industrielles. He was also awarded a chaire d'Excellence by the Fondation Sciences Mathématiques de Paris. Most recently, he was awarded the 2013 Thomas J.R. Hughes Medal by the United States Association for Computational Mechanics.

Ronald Probstein

Professor Emeritus Ronald F. Probstein recently received the 2013 AIAA Pendray Aerospace Literature Award from the American Institute of Aeronautics and Astronautics (AIAA).

Themis Sapsis

Assistant Professor Themis Sapsis was named the first holder of the American Bureau of Shipping Career Development

(continued on page 27)

Student Awards

Undergraduate

Alfred A. H. Keil Ocean Engineering Development Award (For Excellence in Broad-Based Research in Ocean Engineering)
Jacqueline Sly, Grace Young

AMP Inc. Award (Outstanding Performance in Course 2.002)
Sean Cockey, Steven Obiajulu

Beaverworks Award (Outstanding Contribution to 2.013 and 2.014)
Jean Sack

Carl G. Sontheimer Prize (Creativity and Innovation in Design)
Katy Gero

Department Service Award (Outstanding Service to the Department of Mechanical Engineering)
Edward Burnell, Herbert Dee, Eric Del Castillo, Fernando Nunez, Guangtao Zhang

Ernest Cravalho Award (Outstanding Performance in Thermal Fluids Engineering)
Wai Hong Chan, Guangtao Zhang

John C. and Elizabeth J. Chato Award (Excellence in Bioengineering)
Jiahui Liang, Shuo Wang

Lauren Tsai Memorial Award (Academic Excellence by a Graduating Senior)
Lauren Kuntz

Lockheed Martin Prize (Outstanding Sophomore in Mechanical and Systems Engineering)
Sterling Watson

Louis N. Tuomala Award (Outstanding Performance in Thermal Fluids Engineering)
Bruce Arensen, Jordan Mizerak

Luis de Florez Award, First Place Winners (Outstanding Ingenuity and Creativity)
Kameron Chan, Jaguar Kristeller

Park Award (Outstanding Performance in Manufacturing)
Angela Chu, Sean Cockey

Peter Griffith Prize (Outstanding Experimental Project)
Bethany Lemanski

Robert Bruce Wallace Academic Prize
Lucille Hosford

Society of Naval Architecture and Marine Engineering Award (For an Outstanding Undergraduate Student in the Marine Field)
Sarah Brennan

Whitelaw Prize (Originality in 2.007 Design and Contest)
Brian Alvarez, David Flamholz, Xiaoyi Ren

Wunsch Foundation Silent Hoist and Crane Awards
Rebecca Colby, Kirsten Lim

Graduate

Abkowitz Award
Maha Haji, Matthieu Leclair, George Papadopoulos, Anna Wargula

Clement F. Burnap Award (Outstanding Masters of Science in the Marine Field)
Brian Heberley

Luis de Florez Award, First Place Winners (Outstanding Ingenuity and Creativity)
Anirban Mazumdar, Federico Parietti

Meredith Kamm Memorial Award (Excellence in a Woman Graduate Student)
Ambika Goel Bajpayee, Jean Chang

Rabinowicz Tribology Award (Outstanding Graduate or Undergraduate Research in Tribology)
Sanha Kim

Thomas Sheridan Prize (Creativity in Man-Machine Integration)
Yashraj Narang

Wunsch Foundation Silent Hoist and Crane Awards
Darya Amin-Shahidi, Cristina Botero, Bryce Campbell, Hyungryul Choi, Christopher Dimitriou, Tian Gan, Jeong-gil Kim, Tapovan Lolla, Nenad Miljkovic, Kyoo-Chul Park, Adam Paxson, Adam Wahab, Zhenlong Zhao

ODGE Graduate Women of Excellence Honorees and Groups
Ambika Goel Bajpayee, Yi (Ellen) Chen, and Maria Telleria; Mechanical Engineering Graduate Association of Women (MEGA Women)

2013 Tau Beta Pi Inductees

Elizabeth (Evie) Adams

Jackson Crane

Eric Del Castillo

Lucy Du

Camille Everhart

Katie Inman

Ryan Madson

Jillian Oliveira

Manuel Romero

Grace Young

2013 Phi Beta Kappa Inductees

Sara Comis

Katy Gero

Laura Gilson

Monica Isava

(Faculty Awards, cont. from page 25)

Chair in Mechanical Engineering, made possible by a donation from the American Bureau of Shipping.

Sanjay Sarma

Professor Sanjay Sarma was named director of the recently formed MIT Office of Digital Learning.

Nam Pyo Suh

Professor Emeritus Nam Pyo Suh was recently awarded the Doctor Honnoris Causa degree from the Universidade Nova de Lisboa.

Yang Shao-Horn

Professor Yang Shao-Horn recently received the International Battery Materials Association's Research Award of 2013.

Michael Triantafyllou

Professor Michael Triantafyllou was recently named Chairman of the Council of the National Technical University of Athens.

Kripa Varanasi

Associate Professor Kripa Varanasi recently received the Society of Manufacturing Engineers' 2013 Outstanding Young Manufacturing Engineer Award. He was also selected to receive the 2013 Bergles-Rohsenow Young Investigator Award in Heat Transfer by ASME. Additionally, the Varanasi Research Group's LiquiGlide was named one of *Time* magazine's Best Inventions of 2012.

Evelyn Wang

Associate Professor Evelyn Wang recently received the Office of Naval Research's Young Investigator Award.

Amos Winter

Assistant Professor Amos Winter was recently named the Noyce Career Development Chair.

Kamal Youcef-Toumi

Professor Youcef-Toumi has been named a Fellow of the American Society of Mechanical Engineers.

Student Snapshots

From top to bottom: 2.678 Electronics for Mechanical Systems, 2013 Commencement, 2013 Doctoral Hooding ceremony ; 2.013/4 presentation

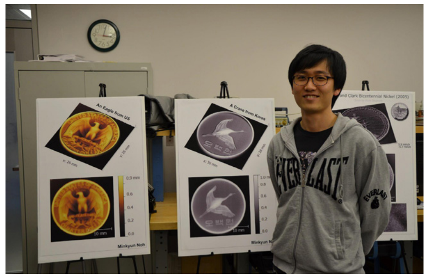
Department News

ronics 2.737 Gets a Makeover

Mechanical engineering exists at the intersection of several science and engineering fields, so it comes as no surprise that MechE courses reflect that. Course 2.737: Mechatronics, which teaches aspects of mechanical engineering, electrical engineering, and control theory, is a great example of our cross-disciplinary curriculum. Through a series of lectures and hands-on labs, students learn elements of modeling, control, instrumentation, analog electronics, digital logic, and real-time implementation.

Last year, the graduate-level course (with approximately 20% undergraduates) was updated by Professor David Trumper and lecturer/lab instructor Darya Amin-Shahidi with completely new labs and an improved curriculum. The new labs are based on a unique macro-scale scanned-probe imager, inspired by an atomic force microscope (AFM). The AFM imager uses a novel self-sensing, self-actuating magnetic probe designed and built by Amin-Shahidi and Trumper specifically for the course.

During the term, students are asked to work on various parts of the imager, such as designing motion controllers, building analog current controllers, and programming



FPGA devices. In the final two labs, they integrate everything they've worked on throughout the course to build a working imager system. This past fall, the students displayed their work during an open house for the course.

Viztu Technologies Acquired

Viztu Technologies, founded by MechE PhD student Tom Milnes and Sloan School of Business graduate Ash Martin, was recently acquired by 3D Systems Corporation. Viztu is the developer of several web-based 3D scanning and printing technologies, including Hypr3D, Zeebl, VizScan, and Drink My Face. These Viztu products, the most popular of which is Hypr3D, offer customers the ability to perform 3D scans with proprietary technology, upload them to a web-based site, and request 3D prints. The resulting models can then be used for product visualization, gaming, and reverse engineering, among other things.

edX Platform Features Its First MechE Course

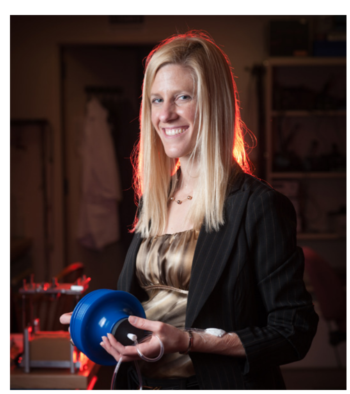
We're pleased to announce that the first MIT MechE course on the edX platform was open for enrollment this spring. 2.01x: Elements of Structure is an online version of 2.01, the introductory-level solid mechanics class in our new flexible 2A program. Beginning on April 15, the course was offered free of charge to the world. Students that complete the assignments and exams receive a certificate of completion. To learn more, visit the course page on edX:

https://www.edx.org/courses/MITx/2.01x/2013_Spring/about

A video with an overview of the course content is also available at: http://youtu.be/iA0gFU4Piy4

Danielle Zurovcik Receives CAMTech Innovation Award

Dr. Danielle Zurovcik (SM '07, PhD '11) started WiCare (Worldwide Innovative Healthcare Inc.) with the goal of bringing high-quality medical devices to low-income countries. The company's first product, the Wound-Pump, a negative pressure wound therapy (NPWT) pump, was recently recognized with an Innovation Award from the Consortium for Affordable Medical Technologies (CAMTech).



Wound-Pump differs from other NPWT pumps on the market because of its unique materials, application method, and size – and its resulting ability to provide lightweight, low-cost, low-energy therapy. Standard pumps cost approximately $100 per day to overcome their extremely inefficient energy usage, preventing low- and middle-income patients from utilizing the therapy. Because Zurovcik's Wound-Pump eliminates such energy waste, she is able to provide a pump that costs less than $2 to manufacture and doesn't require electricity.

WiCare's Wound-Pump was chosen from among 80 other proposals for its innovative technology, potential for widespread public health impact, and clear path to commercial success. For more information on Zurovcik's Wound-Pump, visit http://mecheconnects.mit.edu/?p=1647

SciAm: Anurag Bajpayee Has Top 10 World-Changing Idea

Post-doctoral associate Anurag Bajpayee, a member of Professor Gang Chen's lab, had one of the top 10 world-changing ideas in 2012, according to *Scientific American*. Bajpayee's work as a PhD student at MIT inspired his idea of directional solvent extraction, or molecular desalination as he likes to call it, for highly contaminated waters, such as those from unconventional oil and gas wells.

While working on a previous project on cryo-preservation at Massachusetts General Hospital, Bajpayee and his team discovered that water was dissolving in soybean oil but soybean oil wasn't dissolving in water – a strange phenomenon within the context of the "like dissolves like" rule. Used in desalination, a solvent-water pair that defies the rule allows for Bajpayee's novel process: contaminated water is added to a solvent, the mixture is heated up, and the water is dissolved into the solvent. The contaminants are rejected and removed, and upon cooling, the pure water precipitates out and is collected. The solvent is reused.

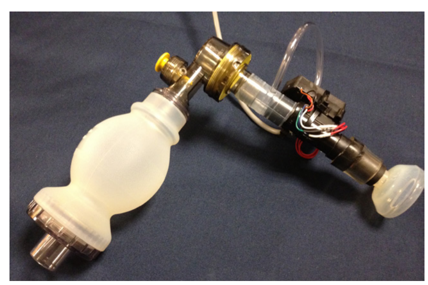
Bajpayee is on a continued hunt for ideal solvents and expects to publish a paper in the near future. In partnership with colleagues, he recently formed a company to commercialize this and other water treatment technology (see page 23 for more information). To read his previous publications on the subject, visit http://rsc.li/1a4VFAE

Read the *Scientific American* article here: http://bit.ly/Tzb84L

MIT IDEAS Global Challenge Awards

MechE PhD candidate Kevin Cedrone led one of two top winning teams in this year's MIT IDEAS Global Challenge. His team's work, the Augmented Infant Resuscitator (AIR), was awarded $10,000 at this year's May ceremony. Joining Cedrone on the team are external members Craig Mielcarz, Dr. Santorino Data, and Dr. Kristian Olson. AIR is an inexpensive add-on device that monitors and records resuscitation performance for existing emergency ventilation equipment. It provides real-time feedback to trainers to help improve their resuscitation technique and training practices.

Cedrone's doctoral research focus is on emissions and efficiency of advanced gasoline engines. He has experience designing and building experiments that include extensive instrumentation of pressure, temperature, and flow systems.



Two other MechE students, Sampriti Bhattacharyya and Stephanie Scott, were part of the Lab-X team that won one of the three Community Choice awards at the IDEAS ceremony. Lab-X promotes socio-economic growth in developing countries through incentive-based educational programs.

Talking Shop: Kripa Varanasi

Thinking Outside the Box Leads to Surface Innovations

Associate Professor Kripa Varanasi's research lab became a sudden media sensation this past year when it unveiled its condiment bottle coating LiquiGlide. A nontoxic, nonstick, super slippery coating made from food-grade materials, LiquiGlide solved a long-time problem that many people can relate to: the struggle to expel a condiment like ketchup, mustard or mayonnaise from its bottle.

Varanasi (PhD '04) and Dave Smith (SM '11), two of LiquiGlide's inventors, recently incorporated around the product. With Smith as CEO and Varanasi as science advisor, the two have plans to expand the coating into several other industries in the future.

What research was your lab working on when LiquiGlide was developed?

We were looking at making surfaces that can overcome existing super hydrophobic surface issues, such as those that accompany impact and phase transitions. That got me thinking about nanostructures. What if you made a surface with a texture that is impregnated with liquid? Instead of trapping air pockets, which is what super hydrophobicity is based on, you have a liquid pocket, which is more stable due to capillarity. If a water droplet impacts an air-pocket-based super hydrophobic surface forcefully, it's going to impale and you lose the nonwetting effect. But with our new method, there's no way to displace the liquid without going to very high velocities. And water cannot condense within these textures either – similarly with frost. When I came to MIT as an assistant professor in 2009, Dave Smith was one of my first students. I discussed this with him and we thought it could be a really interesting thing to look at.

We were both very interested in commercialization and debated the best application for this discovery. Meanwhile, we learned about the problem of dispensing product from bottles. It's something the whole consumer packaging industry struggles with, not only out of bottles but also out of production vats. Some companies lose up to 20% of their product during this process. So we started looking at condiment bottles. We never expected it to become the phenomenon that it did.

It was a bit serendipitous then?

Yes, consumer packaged goods (CPGs) was not on my research agenda [laughs]. But once we started applying the coating to the CPG industry – triggering our participation in the MIT $100K Competition and the subsequent media frenzy over LiquiGlide – we realized that it's a great place to start because its commercialization time is very quick. We also came to the idea that the coating can be applied to health and beauty products too, which is an even bigger market. LiquiGlide is a solid-liquid coating, which means it can be applied to many different products but that each needs its own combination of materials. It's a new paradigm of coatings. We have all the rules and recipes to adjust the coating as necessary. The science of that is captured in a phase diagram. Our goal with LiquiGlide is to apply it to many different industries. We plan to have a CPG division, an aviation division, an energy division, a health and beauty division, and so on.

What is it about the commercialization process that appeals to you?

I am driven to take the science and technologies we develop in the lab to practice. I believe that surface technologies can be useful in improving efficiencies in many areas, whether it be energy, water, or consumer packing. I want to see this research go in and deliver the benefits to sponsors and the general population. I have tried to instill this idea in many of my group members. Dave took it to heart.

In my group, we patent a lot. We have had more than 20 patents since I started my lab. MIT is a great place for innovation and commercialization. The entrepreneurial ecosystem here is excellent; we have received help and support from so many places, including some of my colleagues; The Deshpande Center; Bill Aulet, managing director of the Martin Trust Center for MIT Entrepreneurship; Venture Mentoring Services; Technology Licensing Office; and many more. The whole network at MIT is very electric in terms of getting your ideas out there and potentially commercializing them. For me, I don't think this is the last startup I will be part of. I think we will have many more.

So you really enjoy the process?

I love it. It's so thrilling. I'm always interested in learning new things, and this was quite an experience in those terms – learning how to talk to lawyers, how to find a lab space, how to raise money, and so on.

Do you have a secret ingredient for innovation?

I think curiosity is probably the most important thing. The second is having a varied background of knowledge and experience. You start to see that you can apply ideas from one realm of science in another. I did work in thermal-fluids, precision engineering, nanofabrication, solid-state physics, electromagnetism, et cetera. All of that was driven by the curiosity to learn new things. I cannot stop thinking about new projects and new ideas. It's like a drug for me. I tell all my students and group members that you can be entrepreneurial in many ways; it doesn't have to be through commercialization. You could be entrepreneurial in the research that you're doing, for example. I always like to think about solving a problem in a way that might seem counterintuitive, to potentially create something that you wouldn't think could happen to give you a big jump in the ultimate performance.

Professor Varanasi is recognized as an emerging leader at the crossroads of thermal sciences, nanotechnology, and manufacturing. The principal theme of his research is the discovery and development of novel nano-engineered surfaces and coating technologies that can fundamentally alter thermal-fluid-interfacial interactions for transformational efficiency enhancements in various industries, including energy, water, agriculture, transportation, electronics cooling, and buildings.

His work has been recognized with an NSF CAREER Award as well as by a DARPA Young Faculty Award. *Time* magazine and *Forbes* magazine have named his lab's invention LiquiGlide one of the Best Inventions of the Year. He was most recently awarded the 2013 Outstanding Young Manufacturing Engineer award by the Society of Manufacturing Engineers. Professor Varanasi is also noted for his teaching in the core undergraduate design, mechanics, and thermal sciences courses.

http://varanasi.mit.edu

MITMECHE

Massachusetts Institute of Technology
Department of Mechanical Engineering
77 Massachusetts Avenue, Room 3-173
Cambridge, MA 02139

Coming in the next issue:

► Education Initiatives in the Department of Mechanical Engineering

Students of the year-long course sequence 2.013/2.014: Engineering Systems Design and Development, led by student "CEO" Jean Sack (SB '13), demonstrate and discuss their optimized autonomous underwater vehicle (AUV) at a year-end presentation in room 3-270. Their new design extends an AUV's autonomous range from 72 hours to 30 days. The course is funded by Lincoln Laboratory through the Beaverworks Initiative and is run like a startup company by Professor Douglas Hart.