MITMECHE

Fall/Winter 2014

Vol. 5, No. 2 Published twice a year

Massachusetts Institute of Technology

MechEConnects

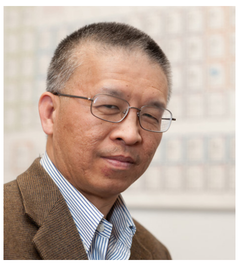
News from the MIT
Department of Mechanical Engineering

The Freedom of Constraint: Engineering for Global Change

It's the vital urgency of emerging markets that forces innovative solutions out of tight constraints – thwarting the popular notion that constraints are always detrimental.

| ► p. 4 |

Driven by a desire to do good



Dear MechE Alumni and Friends,

As engineers, we passionately follow our curiosities and delight in new discoveries and inventions. But we are also driven by a desire to do good in the world and make a positive lasting impact on the lives of others.

We feel it is our duty to leave the planet in better shape than we found it and are lucky enough to have the opportunity to do so. Faculty members and students in the Department of Mechanical Engineering are working to build practical solutions to global challenges, whether that be clean energy, water and food shortages, security issues, transportation challenges, or environmental concerns.

Conventional wisdom says that users in developing countries can't afford the steep prices of high-tech products and that pre-existing solutions simply need to be stripped down and repriced, regardless of how useless or unreliable they may become as a result. But MechE faculty members don't agree. They have traveled around the world and interacted with all types of people. They know that the most valuable solutions are considerably more multi-faceted than a rote process of cutting, stripping, and pasting.

In this issue, you will read about how Professor Ghoniem and his group are working in rural India to develop optimized devices for biomass energy usage and storage. You will hear about Associate Professor Maria Yang and her researchers' processes for user-centered design for emerging markets, and Associate Professor Rohit Karnik's search for a portable blood analysis device. Assistant Professor Amos Winter describes his research group's collaboration with users and stakeholders throughout the design process, from the initial stages of brainstorming to delivering the final product.

You will also hear of our many exceptional students and their passion for helping those in need throughout the world.

Of his educational collaborations with Skoltech University and King Fahd University of Petroleum and Minerals (KFUPM), Professor Warren Seering he said, "We're in competition with ignorance, and all universities are on the same team." Extending this metaphor, we are in a competition against poverty, sickness, aggression, danger, and poor quality of life – and we're all on the same team.

As always, thank you for your continued support.

Sincerely

Gang Chen, Carl Richard Soderberg Professor of Power Engineering and Department Head

Massachusetts Institute of Technology

Fall/Winter 2014 | Vol. 5, No. 2 | Published twice a year

MechEConnects

News from the MIT
Department of Mechanical Engineering

► mecheconnects.mit.edu

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 leading-edge by providing in-depth instruction in engineering principles and unparalleled opportunities for students to apply their knowledge.

Table of Contents

ON THE COVER: The Leveraged Freedom Chair, principally invented by Assistant Professor Amos Winter and commercialized by GRIT, a company founded by Winter and MechE alums Tish Scolnik (SB '10), Mario Bollini (SB '09, SM '12), and Benjamin Judge (SB '11, MEng '12).

Contact MechE

Department of Mechanical Engineering
Massachusetts Institute of Technology
77 Massachusetts Avenue, Room 3-174
Cambridge, MA 02139

E-mail: mecheconnects@mit.edu

mecheconnects.mit.edu
facebook.com/mitmeche
twitter.com/mitmeche
youtube.com/mitmeche

Newsletter Staff:

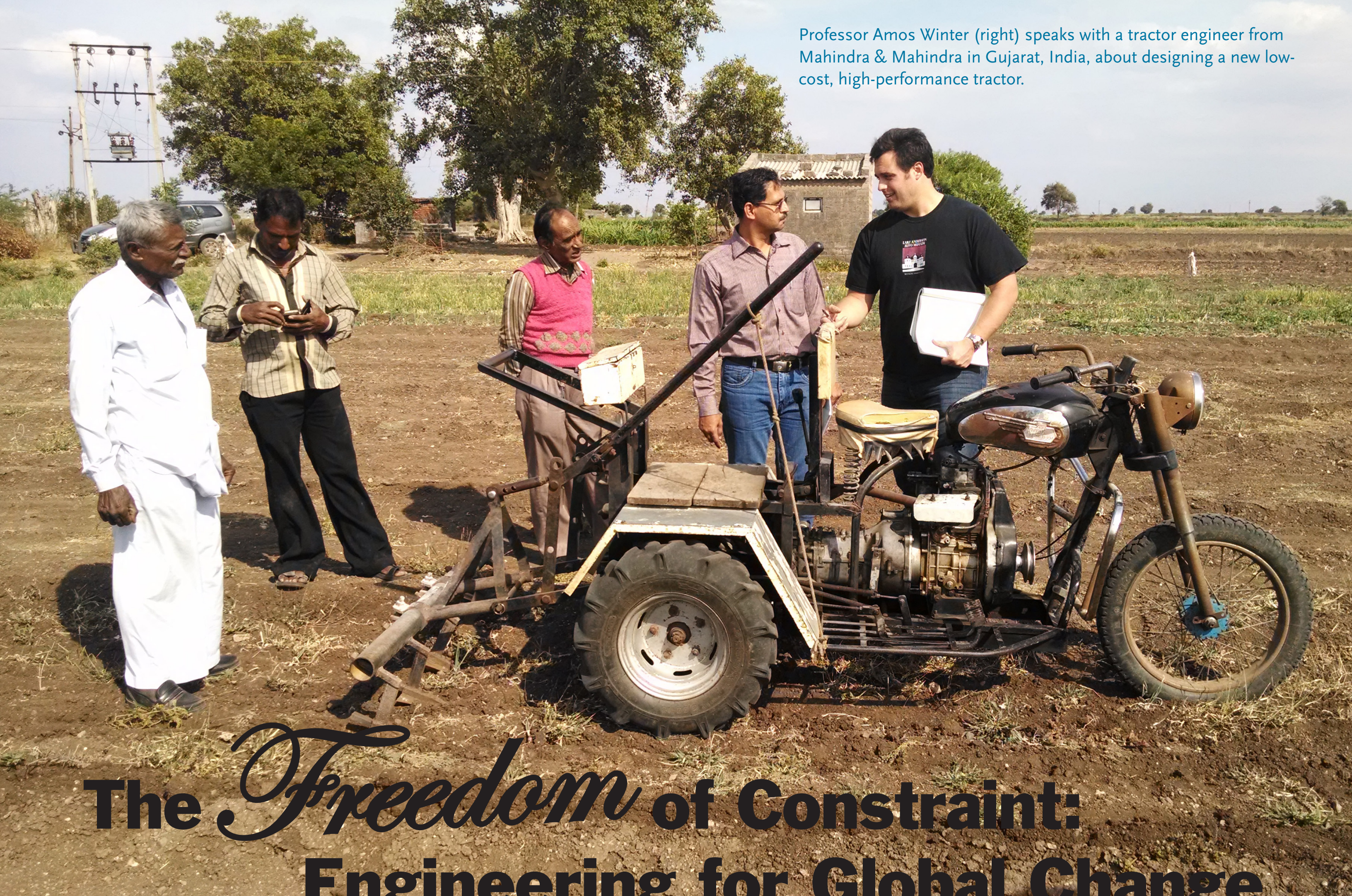
Alissa Mallinson
Managing Editor

Professor Thomas Peacock
Media Moghul

B. Harris Crist
Webmaster

Wing Ngan
Designer

Tony Pulsone, Jasmine Florentine, John Freidah, Josh Ramos
Photography Credit



Professor Amos Winter (right) speaks with a tractor engineer from Mahindra & Mahindra in Gujarat, India, about designing a new low-cost, high-performance tractor.

The *Freedom* of Constraint: Engineering for Global Change

by Alissa Mallinson

You've probably heard of MechE alum and Associate Professor Hugh Herr (SM '93), head of the Biomechatronics group at MIT Media Lab.

The TED Talk he gave earlier this year sparked a flurry of media attention when he unveiled his newest bionic limb, BiOM. The power of Herr's high-tech prosthetic ankle-foot – biomechanics meet microprocessors to emulate a natural gait – became immediately clear when Adrianne Haslet-Davis, a dancer who lost her foot in the 2013 Boston Marathon bombings, danced the rumba across the stage in her first performance since the attack.

It was quite a sight.

Now imagine another amputee, Ashok, who lives and works in India as a farmer. He needs his job just to put food on the table, which, by the way, he has to sit down in front of to eat dinner with his family. Traveling independently on uneven terrain to his field is also a necessity, as is sitting Indian style as he prays.

But earning only about $300 a year, he will need to work for approximately 250 years before he can buy a high-tech prosthetic from the US. He has significantly less money than his rich-world counterparts – yet considerably more urgency.

"More times than not when we look at a technical problem in a developing country, there's already a solution that exists in the rich world," says Assistant Professor Amos Winter. "But for a variety of reasons, that solution usually does not map over –it's either too expensive, not reliable enough, or simply doesn't solve their particular problems.

"So when you look at these really compelling technical problems in the context of developing countries, there is no known solution."

These seemingly contradictory emerging market requirements of low cost and high performance make that perfect solution even harder to find.

"When you start looking into the requirements, the technology might have to be 10 or 1,000 times cheaper than what we have in the Western world but still deliver similar levels of performance," adds Professor Winter. "In order to do that, you have to create a disruptive solution completely off the spectrum of what's currently being done."

It's for this reason that Professor Winter enthusiastically embraces the technological constraints he faces in his research projects and in fact has placed them at the cornerstone of his lab group's strategy – not least of which is their signature in-the-field detective work and unusual focus, at least in academia, on bringing their products to market.

Graduate student Jasmine Florentine (SB '11) speaks with villagers in India to identify the best ways to solicit user needs.

This interest in the end goal requires his research group to consider factors that many engineers can skip right over, such as social norms, local politics, in-depth economics, and topographical details, in order to build mechanical solutions that will realistically get put to use. Just like people in rich countries who have lost their legs, Ashok too wants something more than just the quick and obvious. He wants to walk normally, pray normally, sit down to dinner normally with his family. But he can't afford much comparatively, so while the ideal solution needs to address his complex and nuanced needs, the technology that supports it has to wax simplistic.

"The question that had not been answered yet was how to modify knee torque so it could replicate a normal human gait," says Professor Winter. "We've worked out the theory behind how knee torque should be adjusted with leg mass and how we could replicate the ideal torque profiles using only simple mechanical elements like springs and friction dampers that are available and affordable in emerging markets. This research has given us a road map for how to design a high-performance, low-cost prosthetic knee."

****

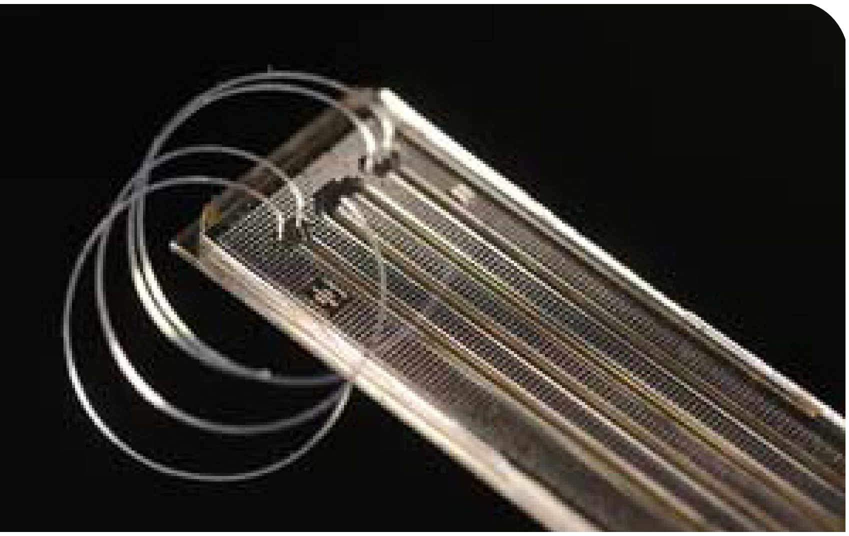
Let's forget about the solution for a brief moment. How can an engineer – especially one working in a rich country like the US – ever reasonably expect to understand the full extent of Ashok's prosthetic needs? His circumstances are so different, his needs so ingrained in his social and cultural circumstances, even his methods of communication are perhaps less similar than what we might imagine.

It's this question of how to design for a user you couldn't possibly understand from a two-hour focus group that Associate Professor of Mechanical Engineering Maria Yang has started to answer.

"US companies generally think of user-centered design in the context of an industrialized country where you have users that are not that much different than you," says Professor Yang. "But what if you are dealing with a market that is culturally different, financially different, linguistically different? It really changes the way you design products.

"Good intentions are just not enough," she says.

Professor Yang's user-centered approach to designing for emerging markets has largely focused on



Associate Professor Rohit Karnik's microfluidic device is designed to rapidly analyze blood by sorting cells based on molecular binding.

"The technology might have to be 10 or 1,000 times cheaper than what we have in the Western world but still deliver similar levels of performance. To do that, you have to create a completely disruptive solution."

-Assistant Professor Amos Winter

understanding a specific type of user: the microentrepreneur. Along with MechE post-doc Jesse Austin-Breneman (PhD '14), Professor Yang has researched several case studies of product development for the emerging-market microentrepreneur to identify patterns of success or failure, and her findings were surprisingly contrary to popular belief.

"These microentrepreneurs were willing to make investments in order to generate more income," she explains, "which flies against the notion that they're looking for the cheapest option. What they are looking for is a reliable, multifunctional product that often includes unexpected features."

For example, Professor Yang's research revealed that a Nokia phone specifically developed for emerging markets was successful in part because it included a multiple-contact-list feature. Figured it out yet? A microentrepreneur would rent his or her one cell phone to several people, each of whom wanted to have their own personal contact lists.

Ideally, designers could fully integrate themselves into the culture they're designing for, but that's not always possible, so another graduate student working with Professor Yang, Jasmine Florentine (SB '11), began developing a process for identifying user needs in foreign contexts. Her process will determine if these users would realistically use certain products, and if not, identify the barriers to usage. Since this kind of testing often relies on behaviors and conceptions that the users themselves may not even be aware of, it requires some strategic psychology. Florentine presents visual presentations, such as storyboards and physical prototypes, to help cut through social and cultural barriers, and makes thoughtful adjustments to her tone or the wording of the questions to help elicit truthful responses.

****

"Identifying the problem is half the battle won," says Associate Professor Rohit Karnik. "I think the most effective solution comes when one is agnostic to one's own expertise and technologies. That allows engineers to see the problem very objectively, and then to think boundlessly about the best solution."

For Professor Karnik, the problem was engineering a simple point-of-care device for rapid blood analysis in developing countries. The current process for blood analysis is quite strenuous, starting with the removal of regular cells and time-consuming incubation, then moving on to centrifugation, multiple washings, and finally laser analysis. His solution had to be a smaller, simpler, faster, and less expensive method of collecting the same data these large-scale centrifuges and multi-step processes do today.

"Our thinking process wasn't constrained by current technology," Professor Karnik recalls. "We allowed – even pushed – ourselves to think about solving the problem with technology that isn't available or even completely understood yet."

Graduate student Kevin Kung explores the application of technology for clean and efficient biomass usage and storage in India.

! Watch a video about Professor Karnik's research: http://bit.ly/1uQcTtH

His research team, in collaboration with Professor Jeffrey Karp and others, chose to develop a microfluidic device that engineers cell movement in such a way that the movement itself could reveal important information about a person's health. The device separates cells by taking advantage of the ways certain molecules bind with other molecules, leaving nature to take its course and allowing the clinician to simply "read" the results. Imagine cells traveling along a path as if they were magnets attracted to a predetermined course.

Professor Karnik envisions that this one-step process and handheld microfluidic device would be deployed in developing countries to, for example, use a drop of blood to determine whether or not to give therapy against AIDS, or take a heel-stick drop of blood from a sick infant to determine the status of his or her immune system.

"It's worth all the effort and risk to try something completely new knowing that if it works it has a good chance of making a significant difference in the world. That potential inspires me," he says.

****

If not for the harsh, bare-bone constraints of emerging markets, valuable discoveries, optimizations, and efficiencies might be overlooked.

"In unconstrained environments," says Professor Ahmed Ghoniem, "you have the luxury of being fascinated by technology for its own sake, and sometimes the technology is all that matters. But in a constrained environment, you have to worry about so many other factors, like can you actually implement the tech where it is most needed? Can you scale it up economically? Is it easy to train locals to use it?"

Professor Ghoniem is developing efficient and cost-effective ways of using clean and alternative energy resources, as well as improving existing energy systems to reduce their environmental impact. One particular method he's focused on is the use of biomass – biological products such as plants or animal products – as a clean, efficient, and flexible energy source.

In rural India, Professor Ghoniem says, biomass is widely relied upon as an inexpensive energy source for heating, cooking, and even cooling, but in so doing it releases toxic gases and is quite unsafe. It is also a naturally inefficient process: While the biomass is being collected, much of it rots and becomes unusable, and a lot of energy is wasted during the burning process itself.

"Biomass in the US is a small fraction of our energy production, but in many places in India, it's a crucial source of energy," says Professor Ghoniem. "While it is desirable to expand biomass usage in the US, in India, it's a life-or-death situation. So we have to do it, we have to do it better, and we have to do it soon."

It's this sense of vital urgency that forces innovative solutions out of tight constraints and – thwarting the popular notion that constraints are always a detriment – frees engineers from some of the boundaries they can unwittingly become accustomed to. Of course the best solutions rely on knowledge of the complex physics and chemistry, but the implementation must also utilize local resources, be simple to build and operate, and be robust enough to survive and adapt.

Professor Ghoniem's research group is answering the alarm call, by building a better process for biomass use, one he calls pyrolysis/torrefaction/coalification. During the process, the biomass is improved by pyrolyzing it in an oxygen-deficient environment at low temperature, and the heat that is generated during this process is recycled. It creates briquettes with charcoal-like elements that can burn more cleanly and be stored for long periods of time without rotting, thus making them easier to transport and sell to other communities. His group's concepts and models are combined with familiarity with the location for fast and effective implementation.

****

"Working on a solution in an environment where resource constraints force you to find the most efficient solution means that you can also bring back a solution to unconstrained environments that is that much better and more quickly adopted."

-Professor Ahmed Ghoniem

High performance, reliability, multifunctionality, and low cost? What's not to love? Emerging markets have severe requirements out of necessity, but the significantly optimized results they yield are valuable in every market. Reverse innovation is this practice of translating an optimized product from an emerging market back to developed markets, complete with their significant improvements and cost reductions.

For example, Professor Winter's Leveraged Freedom Chair (LFC) recently made its US debut after originally being designed and deployed in rural developing areas. "When we were developing the LFC for emerging markets, not only did we have to decrease the price point by 10%-40% compared to the standard US cost but we actually had to add performance on top of it," he says. "We were able to do it, and now we're bringing this upgraded wheelchair to the US and disrupting the market here as well. The LFC is a truly global product."

"Real-world problems are human-driven," says Professor Ghoniem. "The need for clean energy, for example, is global. Perhaps working on the solution in an environment where the resource constraints force you to find the most efficient or economical solution means that you can also bring back a solution to unconstrained environments that is that much better and more quickly adopted."

Indeed, it does. Professor Winter explains that part of the reason his company GRIT – cofounded along with three MechE alumni – Mario Bollini (SB '09, SM '12), Benjamin Judge (SB '11, MEng '12), and Tish Scolnik (SB '10) – decided to develop an upgraded LFC for US and European markets was because of the interest they were receiving from those markets, both from individuals as well as organizations such as the US Department of Veterans Affairs (VA). When GRIT opened a Kickstarter campaign to fund their first run of US-market LFCs, they reached their funding goal within five days.

And the cycle of innovation continues – *reverse reverse innovation*, as Professor Winter calls it. GRIT is now looking at innovative features from the US-version LFC with an eye toward bringing them back to the emerging market for an ultra-optimized wheelchair that never could exist without the freedom that those market constraints exposed in the first place.

Mens et Manus Around the World

MechE Faculty Guide Cross-Cultural Interest in Replicating Teaching and Research

by Alissa Mallinson

Travel to China, Russia, United Arab Emirates, or Saudi Arabia, and it shouldn't take too long to feel like you're right back at MIT.

That's because each of these nations houses at least one – in some cases, more than one – MIT-based education or research institution. Some of these partnerships go back a long way, while others have been freshly formed, but they all have roots in the MIT spirit of global cooperation, creation, and innovation.

The MIT-SUTD Collaboration is a recent partnership, focused on education and directed by MechE's Professor John Brisson, while The Singapore-MIT Alliance for Research and Technology (SMART) stems from an old friendship with Singapore that originally began with a distance learning setup at MIT for students in Singapore. Nowadays, SMART is focused entirely on research, entrepreneurship, and post-doctorate education. From 2008 to 2012, MechE Department Head Emeritus Rohan Abeyaratne directed the program, which includes five tracks in infectious disease, environmental sensing and monitoring, biosystems and micro mechanics, transportation, and low-energy electronics.

Among the roughly 60 MIT faculty members involved in SMART are several MechE faculty, including Professors Nicholas Patrikalakis, Michael Triantyfallou, George Barbasthatis, Roger Kamm, Harry Asada, Peter So, Yang Shao-Horn, Evelyn Wang, and Tonio Buonassisi. For faculty, the SMART campus provides many unique research opportunities that don't exist in the US – for example access to clinical data on malaria – as well as new custom-built labs with state-of-the-art facilities.

Professor Wallace (in white) stands with faculty from KFUPM.

"SMART is a very lively place," says Professor Abeyaratne, "because of the dynamism the MIT faculty bring into the mix with their signature entrepreneurial spirit and because of the deep collaborations that have been built with faculty from Singapore's universities and research labs."

Even before SMART, MechE was sharing its well oiled pedagogical processes and research projects with KFUPM, through a partnership led by Professor John Lienhard, director of the Center for Clean Water and Energy at MIT and KFUPM.

With the help of Professors Warren Seering, Kamal Youcef-Toumi, and Maria Yang, Professor David Wallace, a highly regarded ambassador for active learning in engineering education, spearheaded an educational transfer to KFUPM, helping to develop a curriculum there that focuses on making and doing, hosting faculty workshops that teach its faculty how to motivate students, designing individual hands-on engineering classes similar to MechE's 2.007 and 2.009, and setting up physical labs, among other things.

"Transferring culture is tricky," says Professor Wallace. "Wherever you are, you need to be aware of what the culture is and what the norms are, and respect them. But beyond that, people are people. They like enjoying themselves, so if you're having fun, they'll have fun too. The desire to learn, accomplish, and realize your own ideas are universal, so I've found that very different cultures can still have a lot in common."

A crucial element of success with these programs has been face time, he says, not just initially, but continuously. Professor Wallace – who spends about one month every year in Saudi Arabia, having already shared his style of teaching with more

(continued on page 19...)

Alumni Spotlight: Megan Smith (SB '86, SM '88)

An MIT MechE Engineer Goes to the White House

by Alissa Mallinson

Megan Smith received her bachelor's and master's degrees in mechanical engineering from MIT in 1986 and 1988, respectively. This year, she was appointed to the position of chief technology officer (CTO) of the United States of America.

A past member of the MIT Corporation, Smith has had a prolific and successful career as an engineer; leader; and science, technology, engineering, and math (STEM) evangelist, one that makes it easy to see why President Obama appointed her to such an important position in the White House.

As CTO, Smith serves as an assistant to the president, advising him and his team on how to harness the power of technology, data, and innovation to advance the future of the United States. Her team's priorities include supporting the administration's push for open data and information, advising on a wide range of technology policy topics, and recruiting more top technical talent to serve in government.

> "To make great things, we need mixed points of view and skill sets."
>
> -Megan Smith, US CTO and MIT 2015 commencement speaker

Smith has been a leader of both established and startup companies throughout her career, including as a product designer at early smartphone technology company General Magic and at popular LGBT online community and portal PlanetOut, which she led as COO for two years and as CEO for an additional five. She joined Google in 2003, where she was vice president of new business development, leading influential company acquisitions, including the technology that became Google Earth, Google Maps, and Picasa. She also served as general manager of Google.org, the philanthropic arm of the company, during its transition to include more engineering service projects. Smith later became a vice president at Google[x], where she co-created SolveforX and co-founded Women Techmakers.

In addition to her impact on the professional tech world, Smith is also well known for speaking out for greater visibility for technical women and underrepresented minorities both today and historically, as well as for work in debugging inclusion challenges in tech. Smith is also recognized for her work on K-12

programs that encourage and support the interest of young girls and boys in STEM.

In reference to a keynote speech titled "Passion, Adventure, and Heroic Engineering" that she gave last October at the Grace Hopper Celebration, Smith wrote, "I [also] focused on the need for diversity in innovation teams. This is not only about fairness, but it also makes business sense – the data is clear that diverse teams simply create better products and companies; to make great things we need mixed points of view and skill sets. We know that diversity can sometimes be more uncomfortable because things are less familiar, but it gets the best results."

Smith will deliver the address at MIT's 2015 Commencement exercises. "MIT has been a leader," she says, "in training the next generation of creative thinkers who will pioneer new technologies, launch businesses, and bring needed solutions to so many of the greatest challenges facing humanity."

Alumni Spotlight: Elliot Avila (SB '14)

Driven by Service and Impact

by Alissa Mallinson

Elliot Avila is a recent graduate of the Department of Mechanical Engineering who has a particular interest in the developing world. As an undergraduate student in D-Lab, he traveled to India and Tanzania, and his senior thesis focused on optimizing the frame of a large cargo tricycle for use as a recyclable transport in Nigeria.

Since graduation, he has also been working on a low-cost process for avocado oil extraction for income generation in Tanzania as part of an International Development Innovation Summit (IDDS) project, and he recently began a new job in Tanzania as a product designer and engineer for the company Global Cycle Solutions, working on a multi-crop thresher.

How did you get involved with D-Labs originally?

I took my first D-Lab class during the fall of my sophomore year, which was followed by a trip to India with a team of students over IAP. The class and the trip really stoked my interest, and I ended up taking a second class and returning to India that summer. Even since those first trips, I've found that the work I'm doing has been really fulfilling. From an engineering perspective, the kind of problems that I work with are intriguing because they're widespread, complex, and require a lot of creativity. You have to spend a lot of time understanding how your product or technology fits within the broader cultural context, because there are a lot of obstacles aside from just functionality. It's a real challenge, which I love. But I'm also really driven by how my work could have an impact on other people. I want people to have the same access to opportunities and security that I've been lucky enough to have. That idea has motivated me to pursue this line of work.

In your opinion, what are the biggest challenges to solve in emerging markets?

Last-mile distribution is a really tough challenge. You can have a life-changing product, but it's worthless if you can't get it into the hands of your users. And if you're doing business in the developing world, the bulk of your potential customers tend to live in remote villages, so it's especially difficult to reach them. Some really outstanding organizations have figured out how to do this kind of distribution, but there is no "one size fits all" solution – success stories vary from product to product, region to region.

What does the WeCycler do? What contributions did you make to it?

The WeCycler is simply a large cargo tricycle, used to transport recyclable waste in Lagos, Nigeria. WeCycler employees ride around and pick up recyclable waste from households along a set route. In return for their waste, the customers get points that they can later redeem for something they might find useful, such as cell phone credit or kitchen appliances. WeCyclers then sell the waste to plastic manufacturers, who recycle it into new products. There's a lot of value created, and it seems that everyone involved ends up winning: jobs are being created locally, customers are getting products they want, manufacturers are using more recycled plastics, and less waste is being thrown on the streets.

I got involved with WeCyclers as part of my undergraduate thesis, in which I used FEA techniques and CAD to examine weak points and strengthen the WeCycle frame. The WeCycles are supposed to carry more than 400 pounds of recycled waste, and they tend to be

(continued on next page...)

used on really bad, muddy roads. For my thesis, I wanted to make the WeCycle sturdy enough to withstand the twisting and bending that it undergoes, without making it too heavy or costly.

Can you describe the tech behind the low-cost avocado oil extraction process you developed?

Oil extraction is, usually, a straightforward and simple process: squeeze something that has oil hard enough, and oil comes out. Avocados have a lot of oil in them, and if you dry them and press them with your hand, you'll actually coat your fingers in it.

Coming up with an oil press isn't the hard part – those already exist – it's coming up with an oil press that works for a rural villager. It's possible for the users we're working with to travel a few hours and buy a solar dryer and oil press from the closest large city, but it would cost them well over $400. When we asked our users how much they wanted to pay for an oil press, the answer was usually between $6-$15. Right now we're primarily investigating the use of a screw press and trying to figure out how we can make one that is both low-cost and food-safe.

What were some challenges you faced in both projects, either technical or in implementation?

With the avocado oil project, the biggest challenge right now is figuring out what scale to work on. Is it better to make a $10 machine for one person to own, or should we concentrate on making a $100 machine to be shared between 10 people? I'm hoping to start involving several community partners at a much higher level soon, allowing them to choose the direction of the project as they see fit.

Working on the WeCycle was challenging because it's really difficult to work on something from abroad. It's hard to have a deep understanding of something that you have yet to actually experience. When I arrived in Lagos, it was clear that some things were worse than I had assumed, but other things were better.

What are you doing now?

Currently I'm a product designer and engineer for Global Cycle Solutions in Arusha, Tanzania. I'm working under a grant from the Gates Foundation to develop a multi-crop thresher, a machine that can theoretically remove the grains from the stalks of the most common crops (rice, maize, sorghum, wheat, barley). Threshing is primarily done manually here in Tanzania, which is both time-consuming and really laborious. But the only other available option is to get a combine harvester, which is unaffordable for most people. We're about to start fabricating a few units of the latest prototype, which we'll distribute for use during the January harvest season. It's an exciting project that has a lot of potential for impact if we can figure out how to make it appropriate for the communities that we're working with. I'll be here in Tanzania at least through May, but I hope to stay for the next few years, as I'm really enjoying everything about it."

Faculty Research: Professor John Lienhard

Electrodialysis Can Provide Cost-Effective Treatment of Salty Water

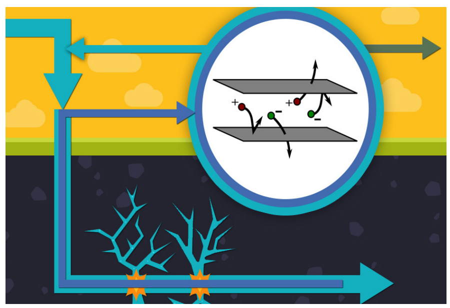
by David Chandler, MIT News Office

The boom in oil and gas produced through hydraulic fracturing, or fracking, is seen as a boon for meeting US energy needs. But one byproduct of the process is millions of gallons of water that's much saltier than seawater, after leaching salts from rocks deep below the surface.

Now researchers at MIT and in Saudi Arabia say they have found an economical solution for removing the salt from this water. The new analysis appears in the journal *Applied Energy* in a paper co-authored by Professor John Lienhard, postdoc Ronan McGovern, and four others.

The method they propose for treating the "produced water" that flows from oil and gas wells throughout their operation is one that has been known for decades but had not been considered a viable candidate for extremely high-salinity water, such as that produced from oil and gas wells. The technology, electrodialysis, "has been around for at least 50 years," says Lienhard, the Abdul Latif Jameel Professor of Water and Food as well as director of the Center for Clean Water and Clean Energy at MIT and King Fahd University of Petroleum and Minerals (KFUPM).

The research team also included graduate student Adam Weiner, graduate student Lige Sun, undergraduate Chester Chambers at MIT, and Professor Syed Zubair at KFUPM.



"Electrodialysis is generally thought of as being advantageous for relatively low-salinity water," Lienhard says — such as the brackish, shallow groundwater found in many locations, generally with salinity around one-tenth that of seawater. But electrodialysis also turns out to be economically viable at the other end of the salinity spectrum, the new analysis shows.

Extra salty

Produced water from fossil-fuel wells can have salinity three to six times greater than that of seawater; the new research indicates that this salt can be effectively removed through a succession of stages of electrodialysis.

The idea would not be to purify the water sufficiently to make it potable, the researchers say. Rather, it could be cleaned up enough to enable its reuse as part of the hydraulic fracturing fluid injected in subsequent wells, significantly reducing the water needed from other sources.

Lienhard explains that if you're trying to make pure water, electrodialysis becomes less and less efficient as the water gets less saline, because it requires that electric current flow through the water itself: Salty water conducts electricity well, but pure water does not.

McGovern, a postdoc in MIT's Department of Mechanical Engineering and lead author of the paper, says another advantage of the proposed system is "flexibility in the amount of salt we remove. We can produce any level of output salinity." The costs of installing an electrodialysis system, he says, appear to compare favorably to other widely used systems for dealing with produced water.

It's not clear at this point, McGovern says, what the optimal salinity is for fracking fluids. "The big question at the moment is what salinity you should reuse the water at," he says. "We offer a way to be able to control that concentration."

(continued on page 17...)

Find out more ▸ **Read the full MIT News article: http://bit.ly/1AP7wgt**

Faculty Research: Associate Professor Maria Yang

Targeting Product Design for the Developing World

by Jennifer Chu, MIT News Office

Designing products for the developing world can be a hit-or-miss endeavor: While there may be a dire need for products addressing problems such as access to clean water, sanitation, and electricity, designing a product that consumers will actually buy is a complicated process. More often than not, such products — even those that are distributed at no charge — go unused due to poor quality, unreliability, or differences in cultural expectations.

And yet, an increasing number of organizations, companies, and startups are targeting products at developing countries for one very practical reason: money. Rising economies like China and India represent potentially massive emerging markets, a large portion of which are made up of small "microenterprises" — informal mom-and-pop businesses of five or fewer people that generate limited income.

In a new MIT study, Associate Professor Maria Yang and her research team suggest that microentrepreneurs are a promising and largely untapped market. They say designers will have more success in developing countries by targeting products to microentrepreneurs, particularly if such products are designed to help make these small businesses money.

"If you can convince them you can make them money, you're most of the way there to selling them your product," says post-doc Jesse Austin-Breneman (PhD '14). "It seems obvious, but if you look at a lot of products out there, they're not really doing that."

Austin-Breneman and Maria Yang, the Robert N. Noyce Career Development Associate Professor of Mechanical Engineering, combed through the literature on product design in emerging markets and identified four case studies in which products had documented success in developing countries: solar-lighting technology,

Find out more ▶ Read the full MIT News article: http://bit.ly/15Aq9gr

cookstoves, drip irrigation, and a line of Nokia cellphones.

From their research, as well as interviews with product designers, the researchers drew up guidelines on how to design for emerging markets. In addition to designing products that can be profitable for consumers, the team advises designers to consider designing for reliability and service, as well as multifunctionality.

"We're trying to refocus people's design thinking," Austin-Breneman says. "For example, rather than figuring out a clever way to fix sanitation, let's come up with a clever way to make people money that's perhaps in the sanitation sector."

Beyond affordability

One of the most successful products in emerging markets, the researchers found, was a line of entry-level cellphones manufactured and distributed in developing countries by Nokia. The company designed phones with a number of features that turned out to have wide appeal for microentrepreneurs: Multiple contact lists allowed cellphone owners to rent out their phones to others, and a time display marking the length of each call served as a method of metering — an easy way for cellphone owners to charge per call.

Nokia also provided reliability via dedicated service vans that traveled to rural Indian villages to fix broken phones. This combination of features that help to make customers money, along with a service plan that established a continuing relationship with the company, likely swayed customers toward Nokia's phones.

Yang and Austin-Breneman found that service and reliability were also big factors for small farmers in choosing a system for drip irrigation — an efficient means of delivering small amounts of water directly to the base of each plant. Farmers tended to choose systems that came with service plans, along with extras beyond the irrigation system itself. For example, some companies offered classes on the types of seeds that would likely be most valuable in the future — information that could help a farmer's bottom line. The researchers also found that modular irrigation systems were attractive: Farmers could easily buy a small system, then add more components as their farms grow.

In the case of solar lighting, products that were multifunctional were most popular with microentrepreneurs. In particular, lights that doubled as cellphone chargers helped small businesses in two ways: The lights kept an owner's store illuminated at night, driving more traffic to it, and the owner could rent the light as a charger for customers' cellphones.

Interestingly, the researchers found that in all cases, microentrepreneurs tended to prefer products that were not necessarily the cheapest available: Factors such as reliability, profitability, and multifunctionality often trumped affordability.

"If a microentrepreneur has, say, a small cart, they don't have a lot of capital to risk, and are more risk-averse," Austin-Breneman says. "But if they believe your product can be serviced and can make them money, that can be successful."

Stephen Anderson-Macdonald, a principal investigator at the London Business School, studies finance and entrepreneurship in emerging markets. He doesn't see many large companies designing products for the developing world — oftentimes, he says, they simply repackage products into smaller, more affordable sizes.

"I wouldn't call that product design," Anderson-Macdonald says. "This study is unique in that not many people are focusing on microentrepreneurs as a market or phenomenon. You can actually design products that are beneficial for them because it's better for their business. There's massive opportunity."

Going forward, the team will be looking through many more case studies, and perhaps focusing on one specific market sector. Yang says they will also dig deeper into the elements of product design to understand how both large companies and small startups can successfully sell to developing countries. For example, while Nokia was able to invest millions of dollars in developing a service network, a startup may not have such resources.

"We want to create design guidelines, based on research, that companies and also independent designers can be inspired by to develop products that are going to be successful, empower microentrepreneurs, and help people improve their lives and communities," Yang says. "That's sort of the Holy Grail, and will make a strong impact in emerging markets."

Watch the video: http://bit.ly/1z3vvM5

Student Spotlight: John Lewandowski (PhD)

Low-Cost Diagnostic Devices for the Developing World

By Alissa Mallinson

When PhD candidate John Lewandowski started working on a low-cost device for the rapid diagnosis of malaria as a graduate student at Case Western Reserve University (CWRU), it was already a fairly well known fact that the disease's biomarkers were magnetic. An interesting characteristic, to be sure, but one that unfortunately hadn't amounted to much.

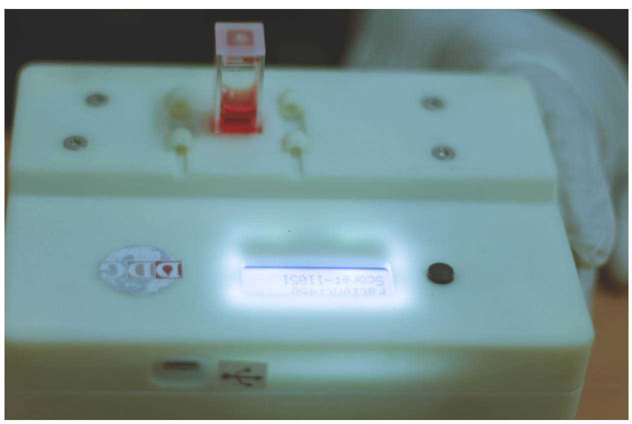
"The problem had always been that the rate of cost and sensitivity were going in the same direction," says Lewandowski. "Engineers would design a device that was very sensitive but also very costly, or conversely, less costly but also less sensitive."

According to Lewandowski, a PhD student in Associate Professor John Hart's research group, it's true that cost and sensitivity are the two most important factors of a successful malaria diagnosis device, but only if the cost is low while the sensitivity is high.

Lewandowski designed a device that was able to balance that relationship and steer it in the right direction.

The trick, he says, is using a low-cost consumable, the object that holds the blood sample in the device. Magnets in the device pulse a magnetic field across the consumable with permanent magnets rotating around the sample, so the thinner (and cheaper) the consumable, the closer the magnets are and the higher the overall accuracy.

"This is a very low-cost approach," explains Lewandowski, "because it quickly aligns the hemozoin and then allows them to randomize. I studied the hemozoin's relaxation rate to design a system that allowed them to relax into a randomized form just long enough to get a readable signal, but not so long that the power requirements or magnetic field reached an inflection point and made the device too expensive. This innovation really separates it from previous techniques that only looked for the magnetic property in the blood."



When malaria parasites make their way into the bloodstream through the bite of a mosquito, they start to digest the red blood cells. But there is part of the hemoglobin they aren't able to digest – which then becomes polymerized and magnetic, with unique optical properties.

As a mechanical engineer, Lewandowski, who had originally wanted to be a medical doctor and studied biology as an undergraduate at CWRU, envisioned a solution that took advantage of these mechanical properties of the disease.

"Another innovative element was the fact that we manipulated the hemozoin markers themselves rather than the polarization," he continues. "Polarization switching may be simpler to implement, but it is more susceptible to false positives. We realized the hemozoin were rod-shaped and that, when pulsed, would absorb more of this 650nm wavelength light on their long axis than their short axis, which is a perfect and low-cost way to distinguish malaria hemozoin signals from hemoglobin or other magnetic confounding effects."

It was Lewandowski's engineering frame of mind brought to bear on his biological knowledge that enabled him to make the crucial breakthrough – one that has garnered both him and his resulting company, Disease Diagnostic Group (DDG), quite a

bit of attention. DDG won the MIT $100K Entrepreneurship Competition this past spring and just recently won the MassChallenge Diamond $100K Prize this past October as well.

His Rapid Assessment of Malaria (RAM) device, as he now calls it – which is reusable and currently about the size of an iPhone box – works by pulsing magnetic fields over the inserted blood sample. If the person is infected with malaria, the magnetic biomarkers in their sample will spin in conjunction with the spinning magnets, and when a laser shines a light through the sample, fluctuating light can be viewed on the other side, allowing a quantitative measure of the parasite density.

The device's portability, along with its high accuracy and low cost, make it a perfect fit for low-resource areas hit hardest by malaria, such as Africa, where 90% of all malaria deaths occur. Transmitted by mosquitos, malaria affected approximately 198 million people worldwide in 2013, killing approximately 3% of those affected, according to the World Health Organization.

"I can see now that my first prototype was actually quite unusable from a global perspective," says Lewandowski. "After taking 2.76: Global Engineering with Professor Amos Winter, I realized the importance of speaking with the end users. When I did that, I received a lot of unexpected feedback. For example, I had always planned on using rechargeable batteries as the power source because that's what you'd do in developed countries. But the users I spoke with in low-resource areas wanted a universal adaptor they could hook up to various sources, such as a phone or car battery. I never would have thought of that, and it completely changed the power requirements of the device."

Lewandowksi and his team at DDG are working on miniaturizing RAM even further by modeling and optimizing the polarization effects and isolating the infected red blood cells before analysis. They also plan to apply the magnet-laser technology to other diseases, such as schistosomiasis, dengue fever, typhoid, and Chagas' disease.

(...Lienhard, continued from page 13)

Filtration first

Before reaching the desalination stage, the researchers envision that chemical impurities in the water would be removed using conventional filtration. One remaining uncertainty is how well the membranes used for electrodialysis would hold up following exposure to water that contains traces of oil or gas. "We need some lab-based characterization of the response," McGovern says.

If the system works as well as this analysis suggests, it could not only provide significant savings in the amount of fresh water that needs to be diverted from agriculture, drinking water, or other uses, but it would also significantly reduce the volume of contaminated water that would need to be disposed of from these drilling sites.

"If you can close the cycle," Lienhard says, "you can reduce or eliminate the burden of the need for fresh water." This could be especially significant in major oil-producing areas such as Texas, which is already experiencing water scarcity, he says.

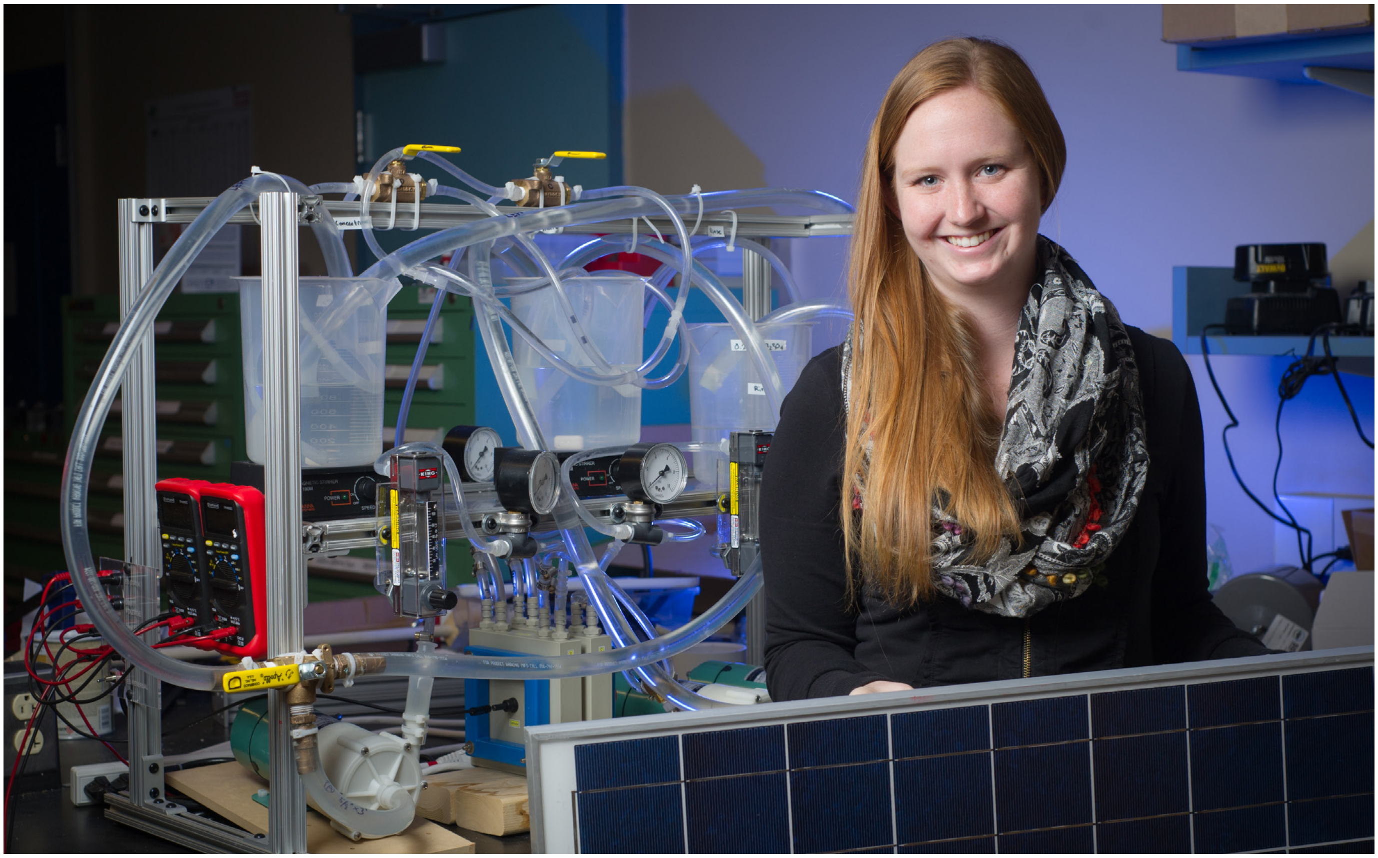
While electrodialysis technology is available now, Lienhard explains that this application would require the development of some new equipment.

The work was supported by KFUPM through the Center for Clean Water and Clean Energy, and benefitted from a Hugh Hampton Young Memorial Fellowship and undergraduate student support from the MIT Energy Initiative.

Student Spotlight: Natasha Wright (PhD)

Adding Some Social to the Science

By Alissa Mallinson



Natasha Wright (SM '14) started her time as a MechE master's student with a trip to rural India. A new researcher in Assistant Professor Amos Winter's GEAR Lab working in collaboration with Jain Irrigation Systems, her goal was to get a read on members of rural Indian communities and their attitudes toward home water filtration systems.

There were already several devices on the market, but most studies indicated that villagers didn't use them regularly, though no one had yet pinpointed the reason why.

"At the time, I was focused on biological contaminant removal," she says. "But as I spoke with villagers, I heard many of them complain about the levels of salt in the water. They didn't like the taste, it made their stomachs hurt, and it left marks on their pots and pans.

I kept hearing the same comments over and over again, even though I didn't even have a question about salt in my survey."

When Wright, a master's fellow of the Tata Center for Technology and Design at that time, came back to the US, she started to do some digging. She discovered that approximately 73% of Indian villages use groundwater as their primary source of water, and that approximately 60% of the groundwater has salinity levels above what people can taste.

"Despite the health benefits of filtration systems, the people I interviewed didn't use them regularly," she says. "The salty taste is one reason why."

Earning a mechanical engineering degree from liberal arts-focused University of St. Thomas in Minnesota, Wright had always been interested in international development and social sciences.

"If you design in a box, whether it's for someone in the US or someone in

Wright surveying villagers in India about their in-home filtatation devices.

Professor Patrikalakis in Singapore as part of SMART.

India, your solution isn't going to be right," she says. "It's the same process in both cases, but when your user is so much different than you, you have to do a lot more to try to get to know them. I find that aspect of engineering for developing markets really interesting."

Wright quickly saw the oft-invisible barriers involved in talking to people from significantly different cultural, religious, and economical backgrounds – and understood the nuances of success. The problem was much more subtle than a simple lack of clean water.

Now a PhD student in GEAR Lab, Wright has sleuthed her way to what she believes is the optimal solution, an electrodialysis (ED) desalination system powered by a photovoltaic system. In off-grid villages of about 4,000 to 6,000 people, energy-hungry reverse osmosis (RO) systems powered by photovoltaics are not economically viable options. But ED systems fit the constraints of these villages quite well. Since they are "modular," they can be scaled down, and they can accept a direct current straight from a solar panel.

"No one is manufacturing the really small-scale ED systems we need," says Wright. "So right now we're trying to answer the question of how the performance and cost laws of big-scale systems scale down to mini systems."

She thinks that by cutting the energy in half through an optimized electrodialysis-photovoltaic combination system that she can beat the off-grid costs of an RO system and ultimately improve the health and lives of people living in rural Indian villages.

Wright's desire to help others doesn't stop with her research. She serves as a Graduate Resident Tutor in an undergraduate dorm, building community among the students and acting as a resource as well as a support system for underclassmen. She also serves as a volunteer for Resources for Easing Friction and Stress (REFS), a confidential student group for graduate students, and she's vice president of the Graduate Association of Mechanical Engineers (GAME).

(...Around, continued from page 9)

than 150 KFUPM faculty – understood from the onset that he wasn't just transferring a particular concept – in many ways they already had that covered – but rather a new style of learning, and teaching.

"It's more about transferring the educational experience than the topics you teach," says Wallace. "Dropping our ideas off at the door and then leaving would not be very impactful, just as it's not impactful to do when you're developing technologies for emerging markets. Working with faculty in their context and following up is critical. Your time together allows you to convey not only how to get things done but also the attitude and ethics that make MIT what it is, and in turn to understand how that will fit into their context."

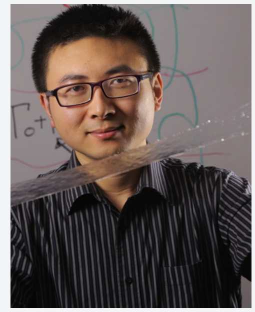
New Faculty

We are pleased to introduce two new faculty members to the Department, Assistant Professor Alberto Rodriguez and Assistant Professor Xuanhe Zhao.

Alberto Rodriguez, Assistant Professor

Alberto Rodriguez earned degrees in mathematics and telecommunication engineering from the Universitat Politecnica de Catalunya (UPC) in Barcelona, and a PhD in robotics from Carnegie Mellon University. He spent a year as a postdoctoral associate at the Computer Science and Artificial Intelligence Laboratory (CSAIL) at MIT.

Professor Rodriguez is the recipient of La Caixa and Caja Madrid fellowships for graduate studies in the US, as well as the recipient of the Best Student Paper Awards at the RSS 2011 and ICRA 2013 conferences. His main research interests are robotic manipulation, mechanical design, and automation. His long-term research goal is to provide robots with enough sensing, reasoning, and acting capabilities to reliably manipulate the environment.

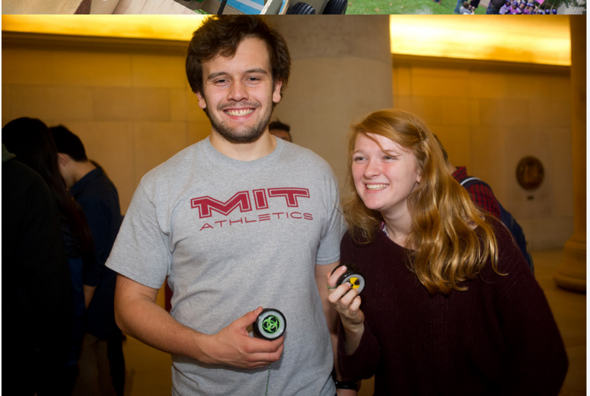


Xuanhe Zhao, Assistant Professor

Xuanhe Zhao received his PhD in mechanical engineering from Harvard University, his MS in materials engineering from University of British Columbia, and his BE in electrical engineering from Tianjin University. Upon finishing his postdoctoral training in biomedical engineering at Harvard, Dr. Zhao joined the faculty of the Department of Mechanical Engineering and Materials Science at Duke University.

Professor Zhao's current research goal is to understand and design soft materials with unprecedented properties and functions, such as active polymers, that may replace muscles and hydrogels tougher than cartilages. He is a recipient of the NSF CAREER Award, the ONR Young Investigator Award, and the Early Career Researchers Award from AVS Biomaterial Interfaces Division.

Student Snapshots



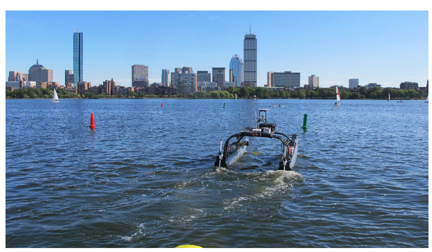
From top to bottom: 2.12: Intro to Robotics final presentation winners, 2.009 team-building event, 2.008 yo-yo final presentations, MIT Maker Faire organizers.

Department News

First-ever MIT Maker Faire attracts nearly 3,000 attendees to campus

This past October, nearly 3,000 attendees ascended upon the North Court of MIT campus for the first-ever MIT Mini Maker Faire. A celebration of STEAM and the fun of making, the faire — part of the Maker Faire series started by the editors at *Make* magazine — featured 110 exhibitors. More than half of these were MIT affiliates, while the rest were local makers. Adults and children, beginners and hobbyists, advocates and experts all made their way through booth after booth of creators, technologists, scientists, engineers, and artists, under three separate circus tents, then over to the go-kart race course and finally on to the panel discussions taking place inside the Ray and Maria Stata Center. Children sat on the edge of their seats in front of the all-day robot tournament as adult audience members cheered on their favorite bots, built and entered into the tournament by MIT and local makers. Attendees stood in awe of the MIT Hobby Shop exhibit, which displayed exquisite craftworks by Hobby Shop members, including instructor Brian Chan (SB ’02, SM ’04, PhD ’09). “What you see here,” said a lead organizer and dual MechE/Engineering Systems Division graduate student Jessica Artiles of the faire’s success, “is that little extra bit of passion that compels us [at MIT] to stay up at night.” The event was organized almost exclusively by MechE students and staff, and sponsored in large part by the Department of Mechanical Engineering.

Team of MechE and CSAIL students wins grand prize at Maritime RobotX Challenge



An MIT-Olin team took home the grand prize this October from the 2014 Maritime RobotX Challenge in Marina Bay, Singapore. The Maritime RobotX Challenge, which was funded by the Office of Naval Research (ONR), invited 15 student teams from five countries to build an unmanned surface vehicle that could best address real-world problems, such as search-and-rescue missions, shipping security, environmental monitoring, fishery management, and marine science. Each team received a skeletal 16-foot vehicle and was challenged to add propulsion, computing, sensor, navigation, and power systems. MIT students equipped the vessel with the MIT Open Source software system called MOOS-IvP, a suite of modules taught in Professor Henrik Schmidt and Dr. Michael Benjamin’s class 2.680 (Marine Autonomy, Sensing, and Communications), of which many team members were alumni. They also included a Velodyne HDL-32E LIDAR sensor, a Hemisphere GPS system, a top-mounted web camera, a four-element hydrophone array, and four separate computing systems to distribute the computational load of the autonomy and sensor processing systems. All four computers communicated with one another using the MOOS Open Source middleware, initially developed at MIT by Paul Newman. The MIT-Olin team also won the Best Paper Award (tied with a team from the Queensland University of Technology in Australia) and the Open Source Award for the technical help they gave to Singapore University of Technology and Design (SUTD) during the competition.

MechE-ChemE Startup Named Gold Winner in MassChallenge

DropWise, a new startup created by MechE Associate Professor Kripa Varanasi; ChemE Professor and Associate Provost Karen Gleason; MechE postdoc Adam Paxson (SB ’09, SM ’11, PhD ’14); and ChemE postdoc David Borelli (SM '11, PhD' 14), was recently named a Gold Winner at the MassChallenge 2014 Accelerator Program, out of 1,600 entrants. DropWise manufactures a "grafted" hydrophobic coating that, when applied to condenser surfaces in power plants, prevents water from building up on pipes and slowing down the condensation process. The coating, which causes water droplets to quickly bead up and shed themselves from a surface, is one two-thousandth the thickness of a sheet of paper so that it itself doesn't block condensation, but it is also strong enough to survive years of steam exposure. In addition to inventing the coating, the team has also developed a novel approach for scaling up the manufacturing process to an industrial level and enabling the coating to stick to surfaces through strong chemical bonds. The DropWise team expects that the new technology can save 0.58 gigatons of carbon dioxide emissions through improved efficiency — more than either solar or wind power.

Inaugural MechE Graduate Research Exhibition Took Place This Past Fall

This past October, the Graduate Association of Mechanical Engineers (GAME) hosted the inaugural MechE graduate research exhibition, sponsored by the Department of Mechanical Engineering, to encourage community, collaboration, and communication skills among MechE students, faculty, and staff. The event – which was organized by GAME President Lee Weinstein, Vice President Natasha Wright, and MechE Day Chair Ranjeetha Bharath, along with Professors Nick Fang and Franz Hover – ran from 10am to 5pm on a Saturday afternoon at MIT's Ray and Maria Stata Center. It featured research presentations – in the form of videos, demos, and posters – from approximately 70 graduate students, who were judged by a medley of MechE students, staff, and alumni. Altogether there were close to 300 attendees throughout the day,

including several MechE faculty and alumni, as well as MechE alum and keynote speaker Mick Mountz, CEO and founder of Kiva Systems. GAME awarded several prizes to the students who scored highest for their presentations. The top prizes went to Meng Yee Chuah, Daniel Dorsch, and Michael Buchman.

Undergrad Develops Robust Distro Optimization Program, Starts Company

A senior in mechanical engineering with a concentration in manufacturing, Doug Coughran, along with his brother Patrick – an undergraduate student at Tufts University studying computer science – realized that their skill sets were complementary. This got them thinking about what they might be able to accomplish if they put their minds together. They spent many family holidays discussing the details of their idea over dinner; now their product is on the market, and their company Foxtrot is garnering quite a bit of attention, not least of which was winning the MIT $100K Pitch Competition this past November. It's a web-based distribution optimization program for small businesses that deliver. The monthly-subscription-based program allows users to enter their distribution information, such as locations and time windows, onto the web site, and it instantly spits back the best route for each driver, for each day, accounting for fuel cost and driver cost. It also offers live rerouting based on changing criteria such as traffic patterns. These optimized routes can be sent directly to drivers' smartphones, and they can be updated in real

time as necessary. The Coughran brothers hope that Foxtrot can also be utilized in developing countries to distribute food, water, and other relief, as well as to reduce carbon emissions around the world.

Talking Shop: Professor Steven Dubowsky

Affordable Water Purification System for Remote Villages

You've spent a lot of time in Mexico setting up your purification system. Can you describe a bit about how it works and what it does?

The system is designed to bring purified water to small remote communities in the world that do not have access to clean water. In many of these villages the residents must drink water that contains high levels of dissolved minerals and biological contamination. The technology we developed uses reverse osmosis desalination to remove dissolved minerals and salts, and ultraviolet radiation to eliminate the biological contaminants. Both of these processes are energy intensive. This energy is furnished in the form of electricity from solar photovoltaic panels. Due to the fact that the sunshine that powers the system is subject to variable weather factors, the system contains an embedded smart microcontroller to optimize the system performance. Since systems for this application are relatively small, they must be run autonomously for a good part of the time. The controller also supports this autonomous operation.

Why did you choose to implement this system in Mexico?

The system was deployed in a small (approximately 500 residents), remote jungle village in the heart of the Yucatan Peninsula of Mexico. The indigenous residents are principally subsistence farmers and beekeepers. Among other things, it was important to evaluate the technology in this environment to determine if the people would accept this relatively sophisticated technology, as well as operate, maintain, and protect it. This is in contrast to many "appropriate" solutions provided by developed nations that are based on relatively primitive methods with limited capabilities.

Did you have unique design or implementation considerations with this project?

Having to assemble a system and test it in a remote field environment without easy access to electricity for our tools – most of which had to be brought from MIT – made this project far more challenging than other international programs we've worked on in the developed world.

Furthermore, we had to provide training materials and hands-on training sessions in both Spanish and the local dialects of the villagers.

Where are you now in the process of implementation?

The system has been completed and in the hands of the community for about six months. It is producing purified water at a cost to the residents that makes it self-sustainable. This cost is a small fraction of the cost of commercially produced water in the region, which is far more expensive than the community can afford. Even at this affordable price, the revenue generates enough income to pay the salaries of the members of the village who operate and maintain it. That will certainly lift their standard of living. In addition, a share of the funds generated go to supporting some of the critical needs of the village. More importantly, the children of the village now have safe, healthy, clean drinking water.

Professor Steven Dubowsky received his BS from Rensselaer Polytechnic Institute and his MS and ScD degrees from Columbia University. His past research has included the development of modeling techniques for manipulator flexibility and of optimal and self-learning adaptive control procedures for rigid and flexible robotic manipulators. His current research includes fuel cell power for mobile systems and photovoltaic-powered clean water systems for challenging field environments. He is a registered Professional Engineer in the State of California and has served as an advisor to the National Science Foundation, the National Academy of Science/Engineering, the Department of Energy, and the US Army. He is a Fellow of both the ASME and IEEE and is a member of the Sigma Xi and Tau Beta Pi honor societies.

MITMECHE

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

Coming in the next issue:

► MechE Robotics

Professor Ioannis Yannas, a member of the National Academy of Sciences and a founding fellow of the American Institute of Medical and Biological Engineering, will be inducted into the National Inventors Hall of Fame in May 2015. Professor Yannas is being recognized for inventing the regenerative principles and collagen scaffolding that enabled "artificial" skin, which not only treats burns but also encourages regeneration of new skin.