

# MechEConnects

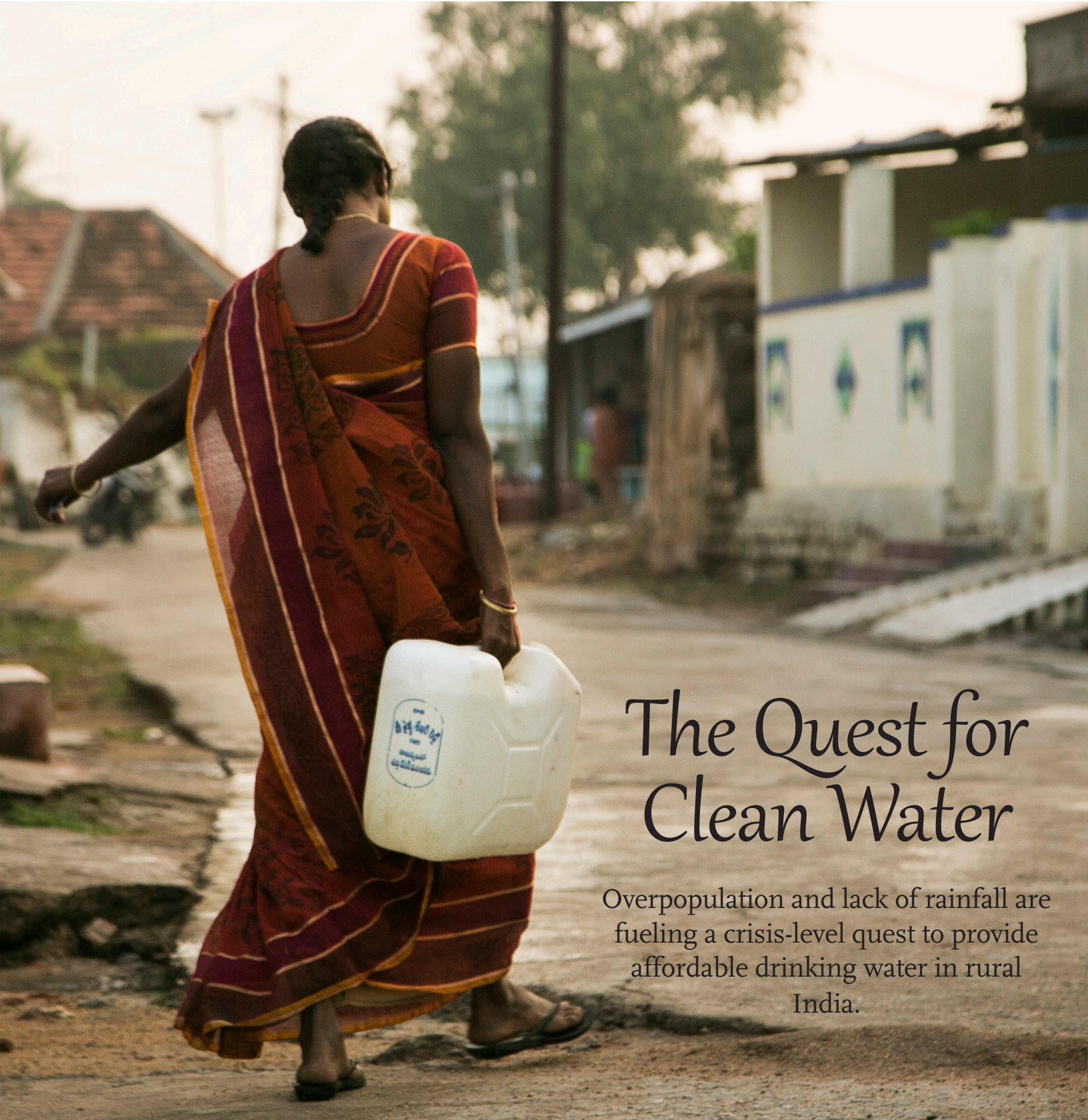
News from the MIT  
Department of Mechanical Engineering

**In This Issue:**

Alum Prakash Govindan is helping to protect the environment with his water purification tech... | > p. 12 |

PhD student Jai Swaminathan is developing a water recovery system for dyeing mills in India... | > p. 15 |

Professor John Lienhard talks shop about the water crisis and why it's everyone's problem... | > p. 22 |

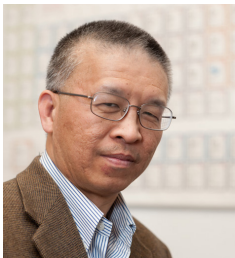


## The Quest for Clean Water

Overpopulation and lack of rainfall are fueling a crisis-level quest to provide affordable drinking water in rural India.



**Our most important job is to create technology that can eventually exit the lab and make a positive impact on people's lives.**



Dear Alumni, Students, Faculty, and Friends,

At the MIT Department of Mechanical Engineering, we focus on many things – from fundamental science and experimentation to making and prototyping. But one of our most important jobs as mechanical engineers is to create technology that can eventually exit the lab and make a positive impact on people's lives, whether that be improving an everyday struggle or solving a major global challenge.

Our faculty and students are solving challenges big and small every day in the areas of health care, innovation, energy, environment, and security. In this issue of MechE Connects, we are highlighting the global water crisis and some of the solutions we are developing in MechE. We are lucky to have some of the best minds in the field on the problem, such as Professor John Lienhard, who was recently named the founding director of the Abdul Latif Jameel World Water and Food Security Laboratory, and who has served as the director of the Center for Clean Water and Clean Energy at MIT and KFUPM since 2008.

In areas like the Middle East and India, where the rainfall is minimal and the population is high, water is scarce and often unhealthy to drink. In developed countries like the US, tragedies like that in Flint, Michigan, have illustrated our own water infrastructure and health problems.

In the issue's feature story, we travel to rural India with PhD student Natasha Wright to join her as she tests her electrolysis photovoltaic water desalination system with villagers and learns more about their needs. We meet another PhD student Jaichander Swaminathan, who is optimizing a small-scale membrane distillation system for the Indian textile industry and enabling zero-liquid discharge. We reconnect with alum Prakash Govindan, who co-founded the water technology company Gradiant based on the desalination system he developed as a PhD student in MechE.

You will also read about natural water filters being designed from sapwood by Professor Rohit Karnik, as well as hear Professor John Lienhard talk shop about his extensive experience researching clean water technologies.

As always, thank you for your ongoing support and friendship.

Sincerely

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

# MechEConnects

News from the MIT  
Department of Mechanical Engineering

> [mecheconnects.mit.edu](http://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**
- **Micro and nano 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.

## Table of Contents

4-10	Feature: The Quest for Clean Water
11	2.500: Desalination
12-13	Alumni Spotlight: Prakash Govindan PhD '12, CEO, Gradient
14	Faculty Research: Professor Rohit Karnik
15-16	Student Spotlight: Jaichander Swaminathan SM '14, PhD Candidate
17	Faculty Awards and Promotions
18-19	Student Awards
20-21	Department News
22-23	Talking Shop with Professor John H. Lienhard V

*On the cover: A woman who lives in Chellur, India, walks home with the reverse-osmosis-treated water she just bought at Chellur's community desalination system. Photo by John Freidah.*

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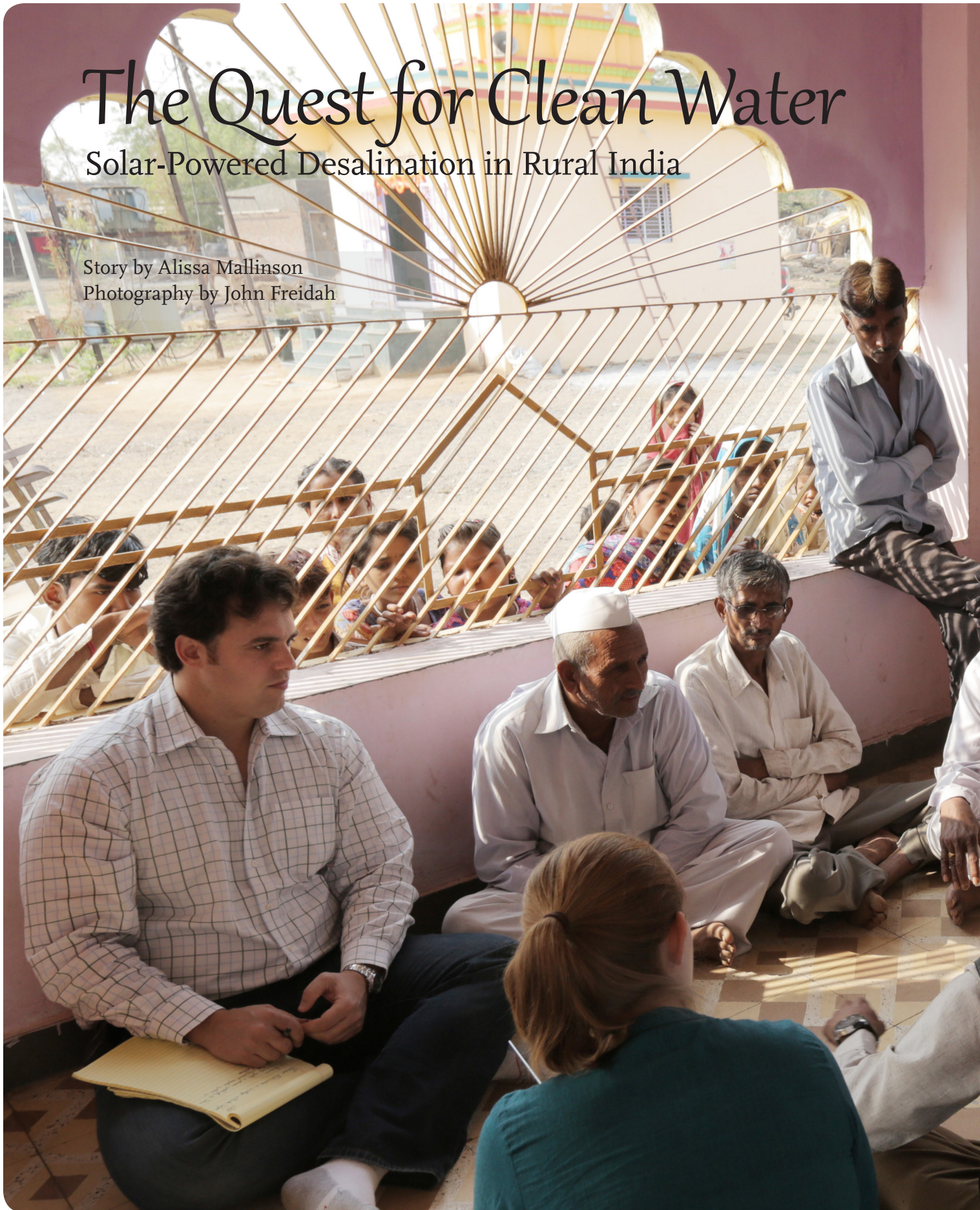
John Freidah, Tony Pulsone  
*Photography Credit*

# The Quest for Clean Water

Solar-Powered Desalination in Rural India

Story by Alissa Mallinson

Photography by John Freidah





## The air was hot and gritty.

Shehazvi had to squint to see past the sun into the edge of town, past the cars and motorcycles whizzing by, past the scorched earth, to where old buildings stood beautiful in their own way, muted pinks and oranges still curving and curling in all the right places. No rain again today.

She and her daughter climbed out of the rickshaw and walked down the alley that leads to their home, 200 rupees lighter than when they left for Jalgaon city earlier that day. That's how much it cost every time she took her daughter to the doctor for stomach pains. The culprit? The salty drinking water.

But there is no grocery store to stock up on bottled water. There is no on-demand tap of drinking water that's already been prepared for her safety and comfort. There is no reliable electricity.

## Everyone's Problem

It's hard to imagine the reality of this situation in the US, where we take 10-minute showers in water better than what many people in developing countries drink on a daily basis. But in India, particularly rural villages, where 73% of the population is drinking completely untreated water, clean water is more than a luxury – it's non-existent.

And yet in the past few years we have uncovered many of our own frightening water problems in the US that have opened our eyes to the fact that this problem isn't limited to developing countries as much as we had thought. The crisis in Flint, Michigan, for example, has revealed a toxic shortcoming in our worn and outdated infrastructure, and we've experienced several consecutive years of significant drought in California.

In fact, on the West Coast, many people get their drinking water from the Pacific Ocean, or from brackish groundwater, because of the lack of rainfall. But seawater and groundwater, which becomes salty from salt molecules seeping out of rocks and minerals, is unhealthy to drink.

"Excessive salt intake can be quite detrimental to one's health, both in the short and long term," says Dr. Maulik D. Majmudar, a cardiologist at Massachusetts General Hospital. "It can cause diarrhea and dehydration in the short term, and continued ingestion of water with high salt content can lead to severe dehydration and development of kidney stones, as well as confusion, seizures, and death in extreme cases."

Because of this health detriment, many state governments on the West Coast utilize desalination systems such as reverse osmosis (RO) to remove the salt and other impurities. In fact, the largest seawater desalination plant in the Western hemisphere was just completed in Carlsbad, California, this past December. It produces 50 million gallons of potable water every day.

That's the solution in the United States, a wealthy, industrialized country. But what happens in a developing country?

"It takes more than just simplifying a solution that exists in a developed country to solve the problems of developing countries," says Assistant Professor Amos Winter, director of the Global Engineering and Research (GEAR) Lab at the MIT Department of Mechanical Engineering. "They don't map over, because when you start looking into the requirements, they might have to be 10 or 1,000 times cheaper than what we have in the Western world but still deliver the same level of performance."

## Not Much Water Anywhere, and Not a Drop to Drink

Shehazvi is a teacher and resident of Mhasawad, a village of about 8,400 people that flanks the Girna River in Maharashtra, India. It's high noon, and she's expecting her water delivery today.

"The water that was supplied is contaminated, and my daughter was always in pain," she says. "I had to repeatedly take her to the doctor in Jalgaon, and it was very expensive. So I started buying filtered water for the health of my daughter and myself. Now the stomachaches and the illnesses are gone. And I don't have to boil the water anymore."

Shehazvi pays 30% of her monthly income for the treated water. But with an average salinity 75% lower than that of the untreated town water, to her, it's worth the cost for the health benefits that come with it.

But despite its benefits, most of the residents of Mhasawad can't afford RO water, which filters out bacteria and desalinates salty water, and thousands of people in the village regularly drink water with a salinity level above 1,200ppm. To put that into perspective, the World Health Organization recommends levels under 600ppm, and the water in Cambridge, Mass., usually doesn't get above 350ppm at its worst.

"Everyone wants to drink the clean water," continues Shehazvi. "But what do they do if they can't afford it? I only get paid 2,000 rupees per month and buying this water has been difficult."

If the lower-income households can't afford the RO-treated water, they definitely can't afford the health costs associated with drinking salty water.

One man living in Mhasawad says he spends around 20,000 rupees a year on his kidney stone problem, and other residents say that stone removal costs about 50,000 rupees. Mhasawad's town leader, an older woman named Vimalbai Chinchore, has had two surgeries to remove kidney stones that the doctors have told her are due to salt in her drinking water.

The townspeople of Mhasawad are particularly concerned about the health of their children, who, according to the teachers in the village, including Shehazvi, have continuous digestive problems and stomach pains that often distract them during school lessons. When the pain gets bad enough, the teachers send the children to the hospital during school.

"They don't feel well," says Shehazvi. "Their stomachs are always hurting. They are always crying."

### "Water is Life"

In order to design a desalination system that actually works in the context of rural Indian villages, Professor Winter and PhD candidate Natasha Wright, a researcher in Winter's GEAR Lab and a fellow of the MIT Tata Center for Technology and Design – which supports this and other GEAR Lab projects for the developing world – knew they first had to develop an in-depth understanding of the problem by visiting the villages and talking directly to the residents themselves.

"We are in the field every six months trying to figure out how socioeconomic factors influence technical factors," says Professor Winter. "We walk the lines between product designers, machine designers, ethnographers, and social scientists, and it's at the convergence

of all those perspectives that disruptive new solutions come together."

In August 2012, Wright travelled to Jalgaon, India, to meet with engineers at Jain Irrigation Systems and partner on the development of a system that would set the dream of the company's founder, Bhavarlal H. Jain, in motion. Himself having grown up in a poor rural village outside of Jalgaon, Bhavarlal's dream was to provide poor villages in India access to affordable potable water.

"Water is life," said Jain. "It is essential to environmental balance. There is no life without water."

The company's plan was to develop affordable home water systems that would remove the biological contaminants from the water, and Wright's first two trips to Jalgaon were spent researching which systems were already on the market and how they were working.

"I went to villages and interviewed women's groups, men's groups, and individual families," she says. "I was focused on the removal of biological contaminants and was hearing that a lot of villagers had filters but weren't using them regularly, only during the monsoon season when the water was brown and visibly dirty. I wanted to figure out how to improve the water and increase the likelihood of filter use to prevent sickness.

"When I reviewed my survey results," she continues, "I realized that everyone was complaining about salt, even though I never even asked about it. They said it tastes bad, leaves marks on their pots and pans, and makes their stomachs hurt."

She also discovered that the salt had a negative effect on the cooking time of rice, a staple of Indian dinners. Many women were frustrated with the amount of time it took to cook their rice using the salty water, turning what is normally a 20-minute cooking process into a 2.5-hour one.

On a logistical level, Wright points out, that 500% increase in time is also a 500% increase in fuel needed to cook their rice – and a proportional increase in the associated costs.

"As outsiders, our motivations are often fueled solely by health concerns," says Winter. "And of course that is crucial, but you have to remember that villagers have almost always gotten their water for free. So to go to a person and say we want you to pay for water that basically looks and tastes the same – what's the value added to them? It's our job to figure out *why* people would choose to buy clean water and include it in our solution."

Wright and Winter believe that by providing desalinated water that tastes good at a price everyone can afford, all villagers – especially those who are poorer and tend to drink contaminated, high-saline water on a regular basis – will be more likely to consistently drink water that's clean and healthy, even if they have to pay for it.

### More People, More Salt

But it goes so much deeper than taste. About 50 to 70 meters deeper, in fact. That is the depth at which many villages in India have to dig new wells to access any water at all.

India's climate is hot and dry for most of the year, and the country as a whole is overcrowded. With almost 1.3 billion

people and counting, it has the second-highest population in the world, with a rainfall that is for the most part reserved for the three-month monsoon season. So while the demand for water increases with population, the water remains scarce, and many places like Mhasawad are forced to dig into the ground for water.

But as water is removed from the ground, the water table – which is dependent on the amount of rainfall – lowers as it becomes overdrawn but not replenished. The aquifers get deeper and deeper to access more water, and the salinity level of the water often naturally increases with depth.

So it's an understatement to say that water is precious and can't be wasted. And yet that's exactly what happens with RO systems that are used with the water in these areas.

RO systems work by utilizing a high-pressure pump to push water through a membrane; the saltier it is, the more energy required to move the water through. Great, you might think: RO should pair perfectly with the brackish groundwater of rural India.

The problem is that after the first pass through an RO membrane, the now-pure water is removed, and what's left is concentrated saltwater.

And now that it's more concentrated, it requires proportionally more power to move it through the membrane – so much more that the cost of the power outweighs the benefits, and manufacturers forgo a second pass to keep the costs down.

As a result, many RO systems in this area have enormous water reject rates. For example, in Chellur, a city outside of Hyderabad, the reject rate is approximately 70%. Meaning that 70% of potential drinking water is wasted before it ever gets desalinated.

To make matters worse, many of these rural villages often don't have reliable access to the electric grid, if they have



In Mhasawad, India, a group of teachers from the local school, including Shehazvi on the left, sat front and center at a meeting with PhD student Natasha Wright this past January to share their concern for the schoolchildren's health as a result of the town's salty water. *Photo by John Freidah.*



it at all. During the summer months in Mhasawad – which are also the driest – villagers have only three hours of electricity in the morning and three in the evening, and many times they don't know which six hours those will be. Any potential desalination solution that needs electricity for power will only work for a quarter of each day, or will be oversized in order to produce the same amount of water in six hours that would normally be produced in 24. But that doesn't come cheap.

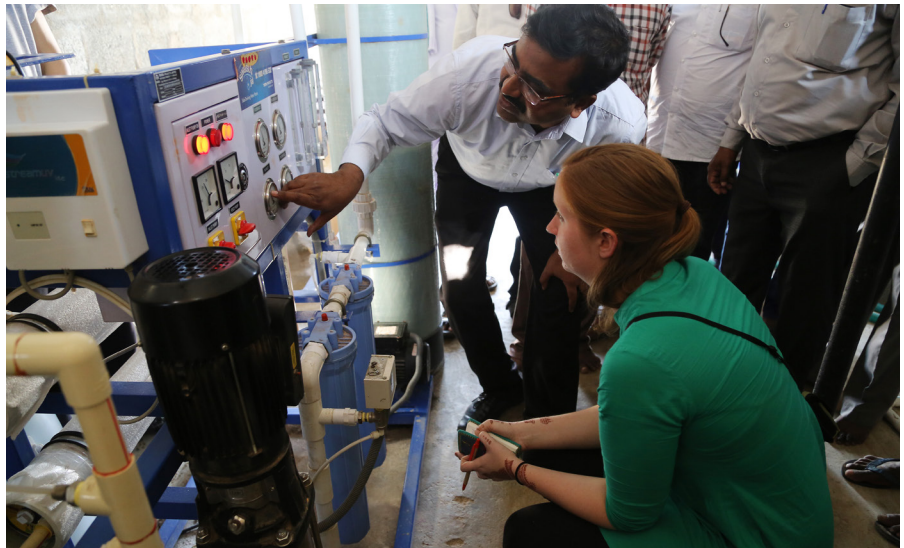
### The Cost of Clean Water

The way Wright and Winter see it, they have to engineer a system for low cost, low waste, and low energy consumption. A mighty tall order indeed, and certainly one that can't be fulfilled just by simplifying a solution that already exists in a developed country.

As product designers, they are looking for new ways to improve the efficiencies in all of these areas.

They started by identifying a system that would work best for the salinity of brackish groundwater in these areas. They chose electrodialysis reversal (EDR), because at the area's typical level of 500ppm to 2,000ppm, it requires 25% to 70% less energy than RO and can recover more than 90% of the feed water. Theoretically, it's also a method that could be used to treat seawater with salinity levels above 30,000ppm, but the cost and energy consumption with current designs are too high (Wright is working on that).

EDR, which has been commercially available since the 1960s, works by pumping feed water through a stack



alongside alternating cation and anion exchange membranes, unlike RO systems, which push the water through membranes. When a voltage is applied across the stack, anions in the water are pushed toward the anode but are blocked by the cation exchange membranes, which only allow cations to cross, and the opposite is true for the cations. In this way, the salt is separated from the feed water and the resulting concentrate stream is recirculated until it is too salty to continue and is pumped into a nearby evaporation pond. Wright's system utilizes UV light to kill biological contaminants in the water as well.

Because water is not being forced through a membrane, the required pressure and relative pumping power is much lower than in RO systems, and Winter and Wright can save energy as a result. This energy gain also opens the door to affordable solar-powered desalination systems, because now they don't need as many solar panels.

So they replaced grid electricity with solar power and can bypass the unreliability of the Indian electrical

grid altogether, decreasing operational and capital costs at the same time. Because EDR uses stacks of exchange membranes that only have to be replaced every 10 years, and that don't require any filters, they cut down on the maintenance costs by eliminating the need to replace membranes or filters often.

The capital costs of their photovoltaic (PV)-EDR system will depend on whether they're able to manufacture their own stacks, but they are targeting a one-time investment of around 755,000 rupees, which is equivalent to the cost of current community on-grid reverse osmosis systems.

In Bahdupet, India, outside of Hyderabad, the local government pays approximately 7,600 rupees per month to power its village RO system, pay the plant operator, and replace filters and cartridges, incurring no loss but making no profit. Switching to Wright's system could save them approximately 3,600 rupees per month, which they could then reinvest back into their people.

[Continued on next page](#)

Clockwise: A woman washes her dishes in front of her home in a rural village outside of Jalgaon, India. A farmer listens to Natasha Wright describe her desalination system. Wright poses with Shehazri. An employee at Jain Irrigation Systems in Jalgaon, India, cleans a solar panel that powers Wright's on-site prototype. A man in Chellur, India, gathers RO-treated water from the village's community desalination system. *Photos by John Freidah.*



### Solving the Solar Power Problem

Wright and Winter have designed, built, and tested their prototype system, and their next step is to implement it in a village outside of Hyderabad, India, where the people are currently using a village-scale RO system that was originally sold to them on loan from a local company called Tata Projects. Wright and Winter have partnered up with Tata Projects to help the company improve their village-scale water desalinations systems and potentially transition from their current RO systems to the PV-EDR systems Wright is designing.

Meanwhile, Wright is looking into ways to make the system more efficient – for example, she's exploring alternate architectures for the EDR stack. At the same time, she is working with GEAR Lab graduate students David Bian and Sterling Watson to cost-optimize the combined solar power and EDR system. Currently, the solar panels are equipped with batteries to store extra solar power and distribute it evenly throughout the day to account for varying levels of sunlight, but they are investigating alternative designs that may allow the solar panels to connect directly to the

EDR stack while maintaining a steady distribution of power throughout 24 hours.

“If we can solve that problem,” says Wright, “we can potentially provide about 250 million people in India who currently drink salty groundwater a safe and affordable source of water.”

*The MIT Tata Center catalyzed GEAR Lab's desal work and, along with Jain Irrigation, enabled them to enter and win last year's USAid Desal Prize. GEAR Lab has also received funding from USAID and UNICEF for this work.*



## 2.500: Desalination

### A Delicate Balance of Efficiency and Cost

By Alissa Mallinson

Desalination – the process of removing salt and other contaminants from water for human consumption – provides almost 90 billion liters of water per day worldwide. And though large-scale desalination technology has been in development since the 1800s, questions regarding energy and cost efficiencies still abound. Yet only a handful of courses are being taught around the world – and very few in the US – to prepare engineers to address these shortcomings.

With roughly 7.6 billion people in the world today, the global population has increased by almost 200% since 1927, and another 2 billion increase is projected by 2050. But simultaneously, rainfall over land remains about the same year over year. In fact, rainfall could become more extreme with climate change, with more intense periods of rain at some times and intense droughts at others. We have increased demands on water but a stagnant and increasingly unstable supply.

“Over a period of a little more than 120 years,” explains John H. Lienhard V, the Abdul Latif Jameel Professor of Water and director of the Abdul Latif Jameel World Water and Food Security Lab (J-WAFS), “the world population will have gone up by a factor of five, which means 8 billion additional people being supplied from the same renewable source of fresh water: precipitation.

“When you get to the point where you’re using all of your available renewable water supply, you have water scarcity. And at that point, water recycling and water conservation become very important. Desalination can help to provide resilience in the water supply and help to meet some of the base demand.”

It’s for this reason that, in 2008, Professor Lienhard created class 2.500: Desalination. With the help of Miriam Balaban, who founded the journal *Desalination* and edited it for more than 40 years, and who has long served as the general secretary of the European Desalination Association, Professor Lienhard built the class’s framework and teaching materials from scratch.

2.500, which is offered to graduate students studying mechanical engineering, chemical engineering, civil engineering, and materials science, covers everything from the basic chemistry of seawater and groundwater, to what makes water unsafe to drink, from the thermodynamics of electrolytes to the Gibbs energy changes in separating freshwater from saltwater. Professor Lienhard is particularly focused on teaching students how to understand the separation process in a given technology and what makes each of them more or less energy efficient.

That, he says, is where there is a major opportunity for improvement in

desalination systems. For example, a well designed thermodynamic power cycle might run at a 60% exergetic efficiency, while a well designed desalination system typical reaches 20-30% exergetic efficiency at best, and often much less. But many of the potential solutions for improving energy efficiency, such as enlarging a surface area for heat exchange, also increase the total cost of the system. Suddenly you’ve got an energy-efficient device that’s not at all cost effective. The issues of cost are particularly challenging in impoverished areas such as parts of India, where the need is dire but the ability to pay is low.

In the US, recent events, such as drought in California, infrastructural failures in Flint, Michigan, and arsenic in New England well water, have revealed that concerns about water aren’t just for developing countries. In fact, in Carlsbad, California, the largest reverse-osmosis desalination plant in the Western hemisphere recently came online, providing water to San Diego County.

“The students who take this class,” says Professor Lienhard, “are very motivated by a desire to help address the world’s biggest challenges. They want to make a difference, and they come into the class eager to learn the tools that will allow them to go out and be useful in the world.”

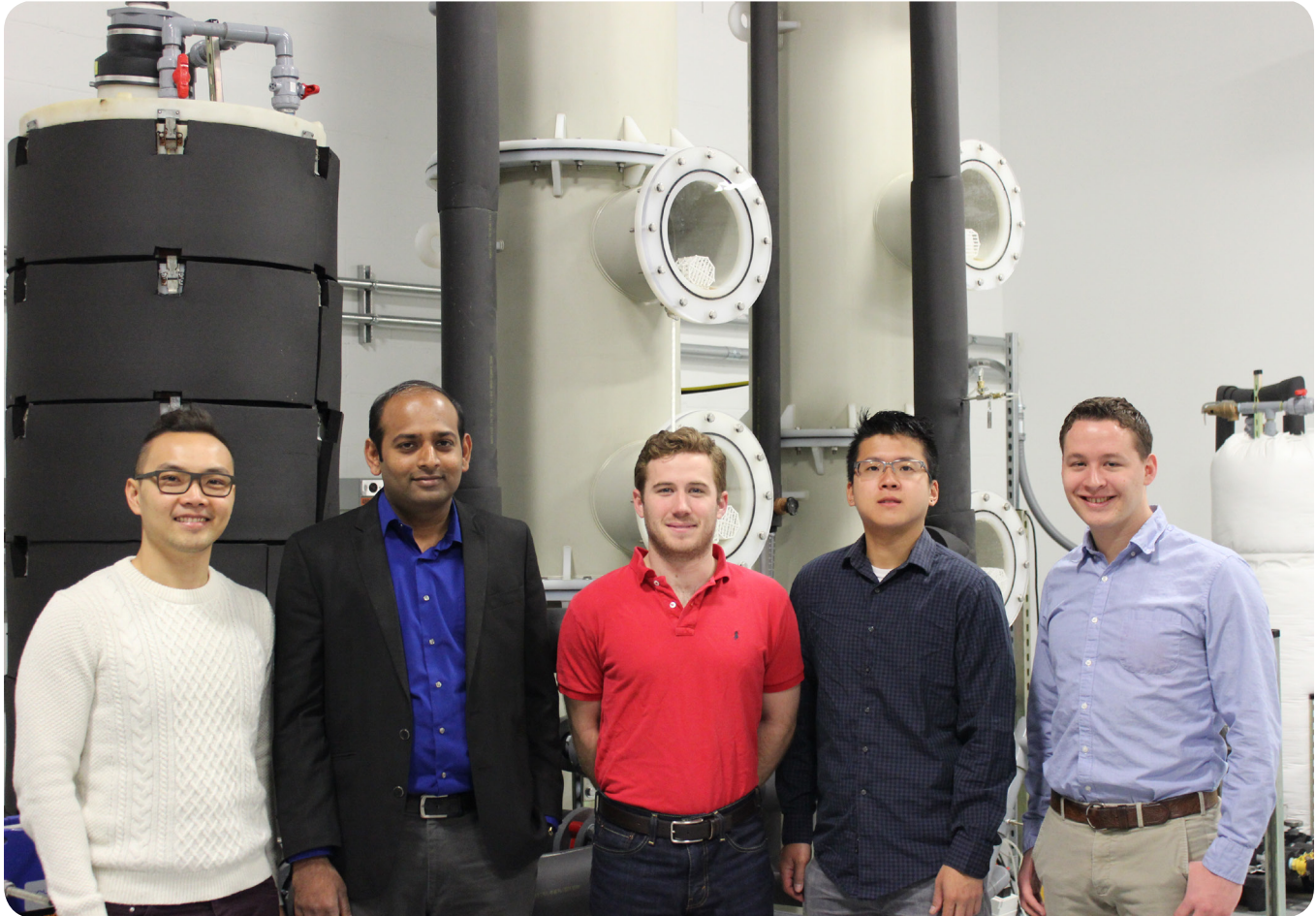
Not a moment too soon.



# Alumni Spotlight: Prakash Govindan PhD '12

## Water Treatment with a Twist

by Alissa Mallinson



From left to right: Simon Choong SM '11 PhD '15, Prakash Govindan PhD '12, Conor Wilson, Steven Lam SB '12, Maximus St. John SB '12.

Prakash Govindan, co-founder and CTO of water technology company Gradiant, remembers walking down to his town center as a young man in Chennai, India, with his brother, Srinivas. The hot sun on their backs, they were on their way to pick up buckets of water that were being delivered by truck to Chennai and haul them back to their apartment until the next shipment came.

“Chennai has a monsoonal climate, getting what is called the ‘return

monsoon,’” Govindan explains. “The problem is that, unlike the direct monsoon, the return monsoon is very finicky. In some years, there is so much rain that there is massive flooding, and in other years it doesn’t rain at all. And when the rain doesn’t come, we don’t have any water. In middle class neighborhoods, you get semi-treated water delivered by truck, but for poorer neighborhoods, they might not get any at all.”

Because Chennai is on the coast, he says, the ingress of seawater infiltrates the groundwater table, and all the borewells in the region turn brackish. The people can no longer drink it because of its high salt content.

It was this personal experience with the realities of the global water crisis that inspired Govindan – who received a master’s degree in mechanical engineering from the Indian Institute of Technology at Madras and his PhD

in mechanical engineering at MIT – to do his part to find a solution.

“Having grown up in Chennai, where we had this massive water problem,” he says, “I knew for a fact that there was a big opportunity in the water space, and I wanted to work in an area where I could make a societal impact. I realized very quickly that, with 1.5 billion people around the world lacking fresh water, this was a way I could do that. And many people weren’t looking at smaller-scale desalination as a solution yet.”

When he joined Professor John Lienhard’s lab as a PhD candidate in 2008, Govindan wasn’t necessarily looking at small-scale desalination yet either. But when he received a fellowship from the Legatum Center at MIT to develop a technology-based business in India, he proposed the creation of small-scale mobile desalination systems for brackish borewells in rural and suburban areas. Professor Lienhard had himself just begun a major research project investigating water purification.

“We started developing technology based on the desalination concept of humidification/dehumidification (HDH), which mimics nature’s rain cycle. As this technology progressed, I met Anurag Bajpayee, my partner and co-founder at Gradiant. He had this beautiful application for my technology in the oil field that could make a massive environmental and societal impact, and the HDH technology was at a price point that fit very well with this application.”

Prakash turned this new application into his PhD focus, and, together with Bajpayee, a PhD student under Professor Gang Chen, it became Gradiant’s flagship technology.

They named it Carrier Gas Extraction (CGE) because it takes a carrier gas, such as air, and humidifies it to produce a cloud-like vapor-gas mixture. Then the “cloud” is condensed to produce rain. The unit operations that perform the humidification (cloud generation) and the dehumidification (rain generation) are both direct contact mass exchangers made using inexpensive, non-metallic surfaces. The energy recovery from the dehumidification process to the humidification process is very efficient in the CGE system. This is facilitated by a thermodynamic concept that was one of the main foci of the R&D performed at MIT and Gradiant.

CGE is considerably less expensive and less complex than comparative technologies, especially for water with salinities around 70,000 ppm or higher, about two times that of seawater – which is just right for water produced as a result of oil production and other industrial processes like mining, textile dyeing, and leather tanning.

In fact, the salinity is often so high for these wastewaters that it is extremely costly and in some cases hazardous to dispose of it. Gradiant’s system can continue to remove fresh water from this increasingly high-salinity water until there is almost nothing left (known as “zero liquid discharge”).

At the same time, Gradiant has developed a second, complementary technology called Selective Chemical Extraction (SCE) that allows for targeted ion removal. Instead of producing 100% purified water, which is often not necessary for the oil industry, this technology targets specific types of ions for removal. SCE allows for a treatment process that is considerably less costly – and one in which the oil company can

cheaply reuse the water that has been partially purified instead of wasting it.

“If a company can reuse the water after a low-cost partial purification, then not only are they saving water and making a positive environmental impact but they are also saving themselves the disposal costs,” says Govindan.

“And water that would otherwise be sourced from fresh water sources, which could be used for drinking or agriculture, is being saved for those uses. Our technology allows the oil company to reuse the water they already own. We are closing that loop and eliminating the disposal and sourcing issues.”

Gradiant, which employs more than 30 researchers and operators – most of which are MIT graduates, says Govindan – also designed, built, and runs three water treatment plants, two in Texas and one in New Mexico, providing a full-service option for oil production companies who want to treat their byproduct water.

“There are many business models you can follow,” says Govindan, “but when you have a new technology within a service model, there is a lot of learning that needs to happen between the lab, the point when you pilot in the field, and the point when you commercially operate. There’s a lot that still needs to be optimized and perfected.” 

# Faculty Research: Professor Rohit Karnik

## Need a Water Filter? Peel a Tree Branch

by Jennifer Chu, MIT News Office (edited for MechE Connects)

If you've run out of drinking water during a lakeside camping trip, there's a simple solution: Break off a branch from the nearest pine tree, peel away the bark, and slowly pour lake water through the stick. The improvised filter should trap any bacteria, producing fresh, uncontaminated water.

In a paper published in the journal *PLoS ONE*, co-author Associate Professor Rohit Karnik and a team of researchers demonstrate that a small piece of sapwood can filter out more than 99 percent of the bacteria *E. coli* from water to produce up to four liters of drinking water a day – enough to quench the thirst of a typical person. They say the size of the pores in sapwood – which contains xylem tissue evolved to transport sap up the length of a tree – allows water through while blocking most types of bacteria.

Karnik says sapwood is a promising, low-cost, and efficient material for water filtration, particularly for rural communities where more advanced filtration systems are not readily accessible.

"Today's filtration membranes have nanoscale pores that are not something you can manufacture in a garage very easily," Karnik says. "The idea here is that we don't need to fabricate a membrane, because it's easily available."

### Tapping the Flow of Sap

There are a number of water-purification technologies on the market

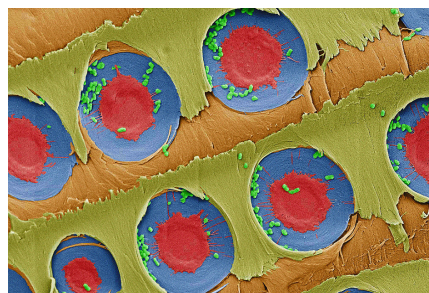
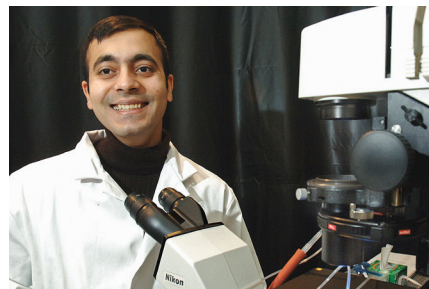
today, although each has its own benefits and drawbacks. For people at the bottom of the economic pyramid, high upfront cost is a major deterrent to using water purifiers.

Sapwood may offer a low-cost, small-scale alternative. The wood is comprised of xylem, porous tissue that conducts sap from a tree's roots to its crown through a system of vessels and pores. Each vessel wall is pockmarked with tiny pores called pit membranes, through which sap can essentially hopscotch, flowing from one vessel to another as it feeds structures along a tree's length. The pores also limit cavitation, a process by which air bubbles can grow and spread in xylem, eventually killing a tree. The xylem's tiny pores can trap bubbles, preventing them from spreading in the wood.

"Plants have had to figure out how to filter out bubbles but allow easy flow of sap," Karnik observes. "It's the same problem with water filtration where we want to filter out microbes but maintain a high flow rate. So it's a nice coincidence that the problems are similar."

### The Size is Right

To study sapwood's water-filtering potential, the researchers collected branches of white pine and stripped off the outer bark. They cut small sections of sapwood measuring about an inch long and half an inch wide, and mounted each in plastic tubing, sealed with epoxy and secured with clamps.



The team flowed inactivated, *E. coli*-contaminated water through the wood filter. When they examined the xylem under a fluorescent microscope, they saw that bacteria had accumulated around pit membranes in the first few millimeters of the wood. Counting the bacterial cells in the filtered water, the researchers found that the sapwood was able to filter out more than 99 percent of *E. coli* from water.

Karnik says sapwood likely can filter most types of bacteria, the smallest of which measure about 200 nanometers. However, the filter probably cannot trap most viruses, which are much smaller in size, or salt.

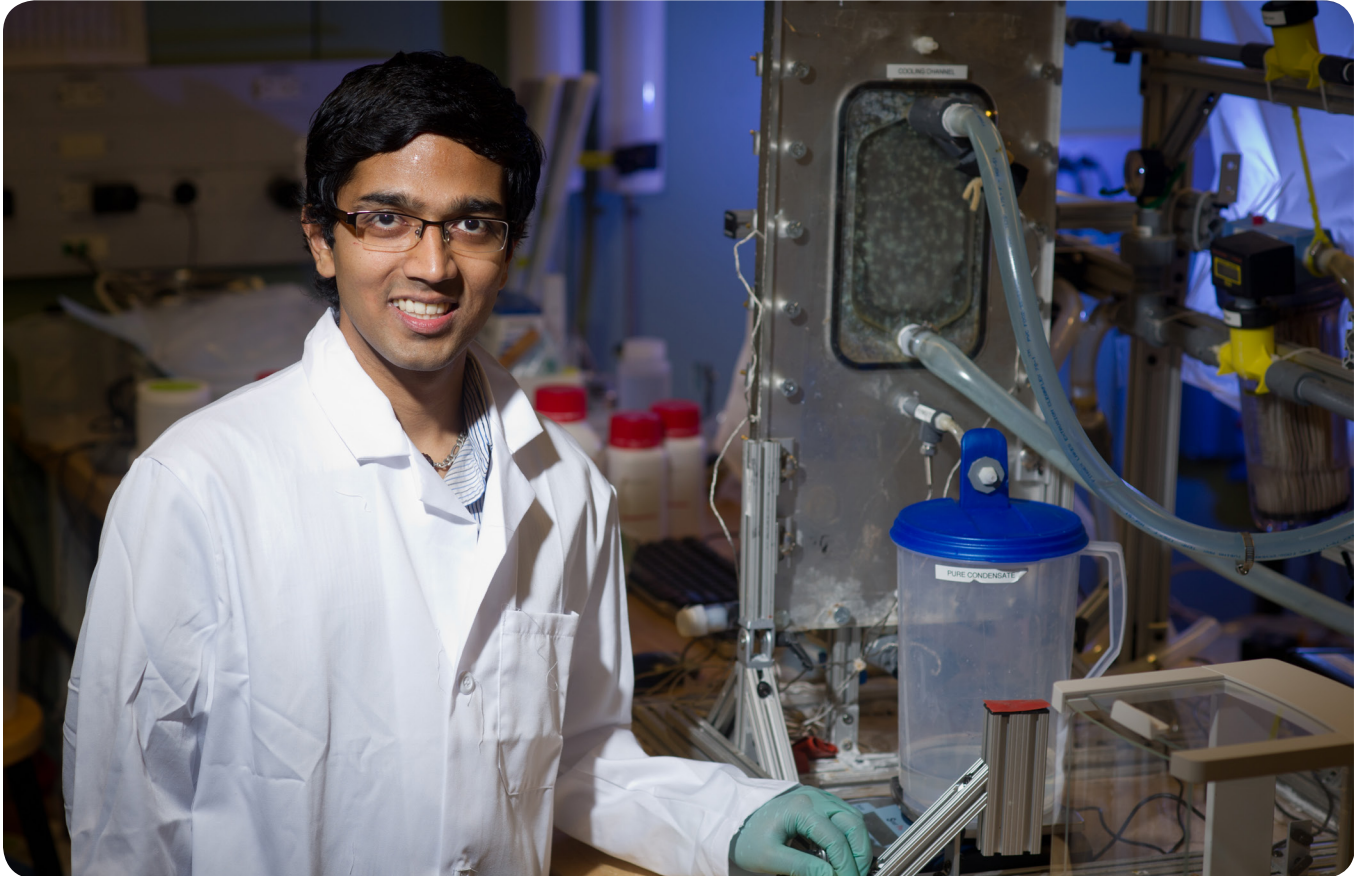
### Making Filtration Devices

Building upon these results, Krithika Ramchander, an MIT Tata Center fellow and student in Mechanical Engineering, is working with Karnik to figure out how to make filtration devices from xylem. "The properties of xylem as a

# Student Spotlight: PhD Candidate Jaichander Swaminathan SM '14

## Recover and Reuse

By Alissa Mallinson



**Despite having two degrees in mechanical engineering, a passion for thermodynamics, and a love for math, PhD candidate Jaichander Swaminathan spends most of his time these days fixing leaks.**

An MIT Tata Center fellow and Deshpande Center grantee, Swaminathan is developing a modular desalination system for small textile dyeing mills in India that are struggling to comply with India's zero-liquid discharge regulations,

which have already forced some mills to close their doors.

Zero-liquid discharge is the idea that, instead of being discharged back into a body of water, such as the Ganges River, potentially contaminated water can be cleaned up and reused. Textile mills in India use water and salts in their dyeing process, and the byproduct is both contaminated and salty.

Swaminathan, who grew up in Chennai, India, has been investigating ways to desalinate extremely high-salinity water in an

energy-efficient way, and has found a great match in this application.

“The problem with textile byproduct water,” says Swaminathan, “is that it can have heavy metals that are toxic in lower concentrations. An average dyeing unit can produce up to 0.5 million liters of water that need to be treated each day.”

### **It Starts with Math**

Having earned his undergraduate mechanical engineering degree from Indian Institute of Technology in Madras and his master's degree

[Continued on next page](#)

in mechanical engineering at MIT, Swaminathan has always loved math.

“It feels good to solve math problems,” says the former Indian National Mathematical Olympiad finalist. “I try to solve them with simple, straightforward logic, but you can still get a lot of answers around that. You try all these potential solutions and then you see patterns. That’s the thing that interests me most.”

As a PhD student under Professor Lienhard, Swaminathan is interested in applying his math skills to the problems of energy efficiency with membrane distillation, which utilizes heat to distill salty water.

For his PhD thesis, he is developing a cheaper, miniature version of a very large desalination system that uses a vacuum to move water through multiple boiling chambers, a system known as multi-effect distillation.

Swaminathan’s mini version will provide smaller enterprises, such as a dyeing mill, with an affordable, on-site method of desalination and zero-liquid discharge. It also reduces the overall power consumption that normally goes hand in hand with the full-scale version, opening up the possibility of utilizing solar or geothermal power instead of electricity.

There are only two problems with the mini version. One is membrane fouling, which Swaminathan spent most of his time as a master’s student

researching, and the other is energy efficiency. Because it’s smaller and made of plastic instead of steel, it’s affordable to purchase and operate, but unfortunately, in its current iteration, it’s also less energy efficient.

But even during his master’s degree research on membrane fouling, Swaminathan had his eye on solving the energy efficiency problem.

“My idea is to replace the air gap, which is usually present between the membrane and the condensing surface to prevent heat loss, with a more conductive gap to increase efficiency.

“The conventional wisdom is that if you make this gap more conductive, you end up losing more heat from the hot site to the cold site, but we’ve been able to show that it’s actually an advantage. In fact, it can lead to two times higher energy efficiency than the conventional configuration.”

Swaminathan produced a numerical model to show that his idea could work, then conducted several experiments to prove its viability.


“After coming to MIT, I’ve done a lot more experimental work,” he says. “It’s been very useful to me and has helped me become more well rounded. As a researcher, I can now do both theory and experiments.”

The system he’s developing can take advantage of the small-scale benefits, but it can also be scaled up quite easily, simply by repeating the

same configuration multiple times. One configuration of his system can produce two to four liters of desalinated water per square meter per hour.

Now that Swaminathan has shown the viability of his idea, he’s started working on new designs, such as spiral membranes, that will help to reduce heat loss even further.


“As I do more experiments,” he says, “I learn useful things I wouldn’t have otherwise learned, such as how to prevent leaks. For example, right now I am testing a new spiral membrane design, and I’ve spent a lot of time just trying to make it leak proof.”

In the end, when the leaks are fixed and the energy efficiency is fully optimized, Swaminathan’s work will save water, money, and energy, and could enable dyeing mills in India to stay in business. 

*(Karnik, continued from page 14)*

filter are not well known,” says Karnik. “We have conducted several studies to advance our understanding of this material, with the goal of being able to design filtration devices.”

Ramchander has already developed a simple process to dry xylem filters without blocking them – a critical problem identified early on in the study – and has demonstrated gravity-driven filtration.

*This research was supported by the MIT Tata Center and the James H. Ferry Jr. Fund for Innovation in Research Education.* 



# Faculty Awards

## Professor Emeritus

**Ali S. Argon** is the winner of the 2015 MSEA Journal Prize.



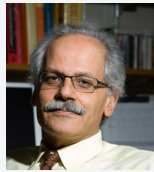
## Associate Professors

**Tonio Buonassisi and Cullen Buie** were two of only 106 researchers who were recently recognized with the prestigious Presidential Early Career Award for Scientists and Engineers (PECASE).



## Professor Ahmed

**Ghoniem** was selected to receive the American Institute of Aeronautics and Astronautics Propellants and Combustion Award for his contributions to aeronautical and astronautical combustion engineering.



## Professor Emeritus

**John Heywood** has been elected as an ASME Fellow.



## Assistant Professor

**Ken Kamrin** is the recipient of this year's Journal of Applied Mechanics Award.



## Professor Seth

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



## Associate Professor

**Pedro Reis** has been selected to receive the Thomas J.R. Hughes Young Investigator Award from the American Mechanics Division of ASME.



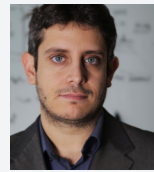
## Professor Emanuel

**Sachs** was elected to the National Academy of Engineering.



## Assistant Professor

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



## Professor Jean-

**Jacques Slotine** will receive the 2016 Rufus Oldenburger Medal.



## Professor Yang Shao-

**Horn** was recently appointed the W.M. Keck Professor of Energy.



## Professor Kim

**Vandiver** was selected for a 2016 CES Innovation Award honoring outstanding design and engineering in consumer technology products.



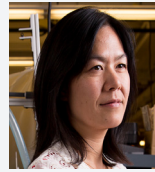
## Associate Professor

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



## Associate Professor

**Evelyn Wang** has been elected as an ASME Fellow. She was also recently appointed the Gail E. Kendall Professor.



## Associate Professors Evelyn

**Wang and Tonio Buonassisi** were appointed Singapore Research Professors for 2016 for their commitment to the mission and objectives of the SMART Program.

## Assistant Professor

**Amos Winter's** article on how to engineer reverse innovation for emerging markets has been selected for this year's Harvard Business Review McKinsey Award for best article.



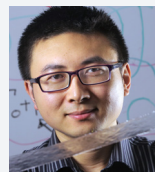
## Associate Professor

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



## Associate Professor

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



## Faculty Promotions and Chairs

**Kostya Turitsyn** and **Kenneth Kamrin** were promoted to Associate Professor. Associate Professor **Sangbae Kim** received tenure. **Thomas Peacock** was promoted to Full Professor. **Alberto Rodriguez** received the Walter Henry Gale professorship, **Betar Gallant** received the Edgerton professorship, **Jeewhan Kim** received the Class '47 professorship, and **Ming Gao** and **Irmgard Bischoffberger** each received a d'Arbellof Career Development Chair.

# Student Awards

## Undergraduate

**Alfred A. H. Keil Ocean Engineering Development Award (For Excellence in Broad-Based Research in Ocean Engineering)**

Brian K. Gilligan, Jorlyn M. Le Garrec

**AMP Inc. Award (Outstanding Performance in Course 2.002)**

Valerie Peng, Daniel E. Rigobon

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

Tyler D. Wortman

**John C. and Elizabeth J. Chato Award**

Camille Henrot

**Department Service Award**

Sina Booeshaghi, Nicholas W. Kwok, Aishwarya Narayan

**Ernest Cravalho Award (Outstanding Performance in Thermal Fluids Engineering)**

John H. Bell, Patrick F. Everett, Elliot D. Owen

**International Design Competition (Outstanding Performance in Course 2.007)**

Austin R. Brown

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

Morgan K. Moroi

**Louis N. Tuomala Award (Outstanding Performance in Thermal Fluids Engineering)**

Martin M. Rencken, Colin M. Poler

**Luis de Florez Award (Outstanding Ingenuity and Creativity)**

Benjamin G. Katz, Moses T. Ort

**Mechanical Engineering SuperUROP Award (Outstanding Performance in SuperUROP Program)**

Bailey R. Montañó

**MIT-Lincoln Lab Beaver Works**

**Barbara P. James Memorial Award (Excellence in Project-Based Engineering)**

Nicholas W. Fine, Camille Henrot, Lauren S. Herring, Laura Jarin-Lipschitz

**Park Award (Outstanding Performance in Manufacturing)**

Gordon Moseley P. Andrews, Cody L. Jacobucci

**Peter Griffith Prize (Outstanding Experimental Project)**

Brian P. Wilcox

**Robert Bruce Wallace Academic Prize**

Trevor R. Day

**Whitelaw Prize (Originality in 2.007 Design and Contest)**

Beatriz A. Gonzalez, Samuel A. Resnick, James V. Roggeveen, Kerrie Wu

## 2016 Tau Beta Pi Inductees

Cyndia Cao

John Drago

Jason Zachary Fischman

Elizabeth Mae Glista

Brittany Bautista

Anuj Khandelwal

Melody Grace Liu

Colleen McCoy

Henry Merrow

Jialin Shi

Krithika Swaminathan

Daniel Vignon

Lara Markey

## 2016 Phi Beta Kappa Inductees

Camille Henrot

Braden Knight

Connie Liu

Andre Wallentin

Kathleen Xu

**Wunsch Foundation Silent Hoist and Crane Awards**

Kathleen L. Xu

**Graduate**

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

Michael Stern

**Luis de Florez Award (Outstanding Ingenuity and Creativity)**

Kathryn M. Olesnavage, Tyler D. Wortman

**Meredith Kamm Memorial Award (Excellence in a Woman Graduate Student)**

Michelle B. Chen

**Thomas Sheridan Prize (Creativity in Man-Machine Integration)**

Kathryn M. Olesnavage

**Wunsch Foundation Silent Hoist and Crane Awards**

Riley E. Brandt, Rupak Chakraborty, Lucille Hosford, Julieth Ochoa, Bolin Liao, Katherine M. Ong, David G. Kwabi, Florian J. Feppon, Karim S. Khalil, Leah R. Mendelson 

**2016 Pi Tau Sigma Inductees**

Natalie Alper

Joseph Babcock

Brittany Bautista

Noam Buckman

Julia Canning

Matthew Cavuto

Justine Cheng

Matthew Chun

Beckett Colson

Tate DeWeese

Isabella DiDio

John Drago

Jason Fischman

Brian Gilligan

Noor Hartono

Sophia Jaffe

Rebecca Kurfess

Lucia Liu

Melody Liu

Joseph Lowman

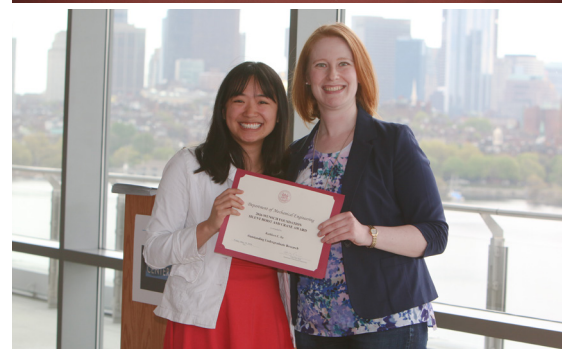
Henry Merrow

Marie Elimbi Moudio

Maximilian Tang

Lampros Tsontzos

**Student Snapshots**

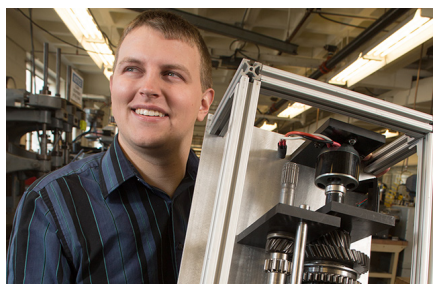


From top to bottom: A student explains her DeFlorez Design Competition entry to Professor Dan Frey; the top winners of the 2.007 Robot Competition pose with Professors Sangbae Kim and Amos Winter; Professor Ioannis Yannas shares a laugh with Department Head Gang Chen at an event honoring his invention of organ regeneration; and graduating senior Kathleen Xu accepts an award for outstanding undergraduate research from Senior Lecturer Dawn Wendell SB '04, SM '06, PhD '11.

## Department News

### PhD Student Daniel Dorsch Wins Lemelson-MIT Student Prize for Invention

The Lemelson-MIT Student Prize is a nationwide search for the most inventive undergraduate and graduate students. This year, PhD student Daniel Dorsch was a winner of the prestigious award in the “Drive it!” category for his invention of the first high-performance, lightweight clutchless hybrid transmission. Dan designed a way to achieve both efficiency and performance by using an electric motor to fill the acceleration lag between gears for seamless shifting. The electric motor can also be used for efficient city driving. Dan received \$15,000 for his invention. In the “Eat it!” category, a team of three MechE undergrads and one grad student – Kale Rogers, Michael Farid, Braden Knight, and Luke Schlueter – won for their invention of the first fully automated restaurant.



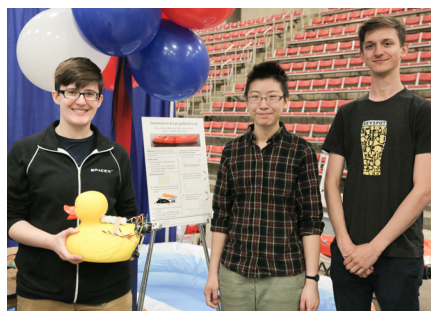
### De Florez Competition Winners Split \$20K in Prize Money

With an impressive array of some of the best gadget and product developments mechanical engineering students have to offer,

this year’s de Florez Competition pitted 25 applicants against each other to compete for a total of \$20,000 in prize money. Entrants do their best to pitch the gizmos and products they’ve designed to a team of judges, who look at each entry’s level of creativity, innovation, practical application, scientific basis, and design skill. The purpose of the competition is to give students a chance to strut their skills and gain school-wide recognition for their ideas and prototypes.

This year’s winners in the category of Graduate Design were: Tyler Wortman, for Tissue Characterization for Skin Cancer Detection and Mapping; tied for second place were Alexandre Girard, for Lightweight Robotic Arms Using Dual-Speed Actuators, and Sahil Shah for Clutchless Dual-Shift Hybrid Transmission Architecture for Performance Applications; and tied for third place were Mark Jeunette for High-Speed Multispectral Camera Array and Peter Chamberlain for the Automated Walker. In the category of Graduate Science, Katie Olesnavage won first place for her Development of a Novel Optimization Objective for Passive Prosthetic Feet. Jerry Wang tied for second place with Nanofluidic Adventures in Extreme Confinement along with Rachel Kurchin for Next-Generation Photovoltaics through Advanced Probabilistic Modeling. Pulkit Shamsbery won third place for A Low-Activation Pressure Online Pressure Compensating Drop Emitter.

In the Undergraduate Design category, Benjamin Katz won first place for Cheap Actuators for Dynamic Robots; Matthew Cavuto won second place for Low-Cost Transfemoral Rotator for Use in the Developing World; and Samuel Resnick and Jacob Rothman tied for third place for Curved Scissor

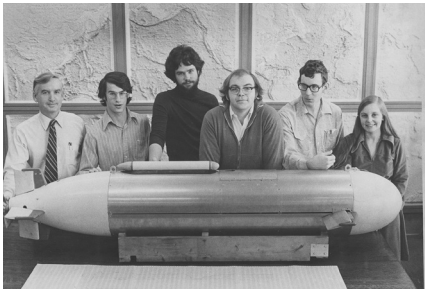


Truss and ProForm Power Rack, respectively. In the Undergraduate Science category, Teddy Ort won first place for A Robotic Helping Hand that Utilizes Visual Feedback to Optimize Human Robot Interaction in Soldering Applications.

### In Memoriam: Dr. A. Douglas Carmichael and Dr. Koichi Masubuchi

Professor Emeritus A. Douglas Carmichael passed away peacefully following a brief illness on November 9, 2015, at the age of 86. He was a highly regarded thermodynamicist with a specialty in steam and gas turbines for ship power and propulsion. A Professor of Power Engineering in the Department of Ocean Engineering at MIT from 1970 to 1996, he was a lead developer of

the first autonomous underwater vehicle. He was also well known at MIT for his mentorship and dedication to undergraduate students.



Dr. Koichi Masubuchi, Professor Emeritus of Ocean Engineering, passed away on April 1, 2016, at the age of 92 years old, in Concord, Mass. Professor Masubuchi was a leading expert in welding science and fabrication technology whose work helped to progress the understanding of welding and the important role it plays in marine and aerospace structures. He spent his first 10 years at MIT focused on solving welding problems NASA was having with its Apollo project. His main areas of expertise were in heat flow, residual stresses, and distortion in weldments; the fracture of welded structures; and welding technologies for underwater and space applications.

### MIT Hyperloop Team Unveils its Prototype

The MIT Hyperloop team unveiled its pod on Friday, May 13, to a large crowd at the MIT Museum in Cambridge. After winning the first round of Elon Musk’s Hyperloop design competition in March of this

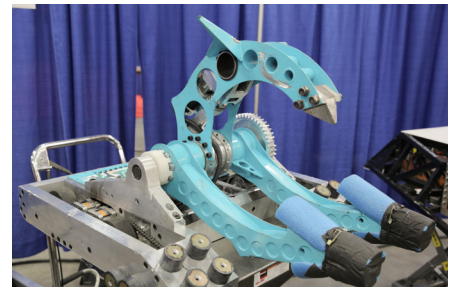
year, the team of 30 MIT graduate students, 14 of which are in MechE, spent much of their free time over the past two months building their pod. The team, which is also comprised of students from the Department of Aeronautics and Astronautics, Electrical Engineering and Computer Science, and Sloan School of Management, is organized into five sub teams, focused on aerodynamics and structures, levitation, vehicle dynamics, electronics and software, and business and marketing. Employing magnets for braking, levitation, and lateral control, the team’s main goal, in addition to proving their design’s viability, is to demonstrate the scalability of the technology. Along with their advisor, Professor Doug Hart, the team of students will travel to Los Angeles at the end of the summer to showcase their pod on the Hyperloop track at SpaceX for the ultimate phase of the competition.



### Calling all Battlebots!

What is it called when multiple 250-pounders battle each other in an arena with hammers, flamethrowers, and spinning blades for the general public’s entertainment? Although it

may sound like an episode of *Game of Thrones*, it’s something much better. It’s Battlebots! A reboot of the original TV show from the early 2000s premieres on ABC this summer starting at the end of June. The new show features more than 10 MechE students and alumni who have joined forces to fight gladiator-style with a twist against heavy-duty bots they’ve built from scratch. “Overhaul” was built by Charles Guan SB ’11 and



Paige Reiter SB ’16. “Sawblaze” was built by Jamison Go SM ’13, Lucy Du SB ’14, SM ’16, Chris Merian SM ’16, John Mayo SM ’16, and PhD candidate Joao Ramos. “Dentist” was built by Rebecca Li SB ’17 and Austin Brown SB ’18. “RoadRash” was built by Frederick Moore SB ’14, Julian Merrick SB ’13, and Cheetiri Smith ‘SB 14. Catch the unveiling of their “be-ot-iful” creations on ABC June 23, at 8pm EST.

# Talking Shop: Professor John H. Lienhard V

## A Resource in Crisis

### What are some of the most important problems to solve when it comes to providing clean water globally?

Depending on where you are, the challenges around water are different. In some places where you have a good infrastructure but still have water shortages, you may want to look at the way water is being used and focus on conservation as the first step. California has made progress this way in dealing with the current drought. In other places, the challenge is a lack of infrastructure. For example, in many parts of Africa, there is no pipe distribution system or water treatment plant and there's not much of an economy to build on. People use relatively little water because they lack easy access, and the approach is often to purify water at the point of use or to provide some very basic infrastructure to aid water collection and distribution. Costs for water have to be kept extremely low. In other cases, you may have dysfunctional governance and no effective regulation of pollutants that spoil fresh water resource: India and China both have problems of this sort. So, the challenges – and the solutions – are different in each situation.

The one problem that is universal is that rising population and higher standards of living are straining water supplies around the world. Fresh water resources that seemed adequate, or even abundant, 100

years ago are overtaxed all around the world. And our environment is suffering as we suck up rivers, lakes, and other supplies for human use.

### These are big problems. How does MIT's School of Engineering, and MechE in particular, fit in to solving them?

Great question! Technology has a big role to play in solving these problems. We can do a lot more to recycle and reuse water, by advanced membrane processes, by advanced biological processes, and by other separation and purification processes. We can find environmentally benign means to convert salt water to fresh water, by driving desalination with solar power and by safely designing the exchange of water with the coastal oceans. We can use information technology – data and sensors – to better manage water consumption and to prevent pollutants from reaching our fresh water resources. And we can make agricultural use of water far more efficient, for example with inexpensive soil moisture sensors and low-pressure drip irrigation. Amazing things are being done at MIT in all of these areas, and the Department of Mechanical Engineering in particular is working on almost every one of these issues.



### How does your research fit in?

My own group's work is focused on how we can reduce the energy consumption of desalination systems, and how we can make those systems robust. We've been interested in both drinking water production and wastewater treatment. We've developed a number of technologies, and in the last few years my former students have gone on to form two companies based on the developments. We've also done a lot of research on the theoretical underpinnings of energy efficiency in desalination.

### Is energy efficiency the key to getting these technologies used?

No, not entirely. What determines the selection of a water treatment system is how much water costs in the end. Energy is part of the cost,

but even for seawater desalination it's only about one third. Capital and operating costs also matter a lot. And these trade off against one another in the engineering process. Usually if you have more area, bigger heat exchangers, more membrane area, larger humidifiers or dehumidifiers, you can raise the energy efficiency – but your capital costs go up proportionally. There's a point beyond which the increase in capital cost adds so much to the price of water that the savings in energy just don't make sense. That tradeoff is really intrinsic to the decision-making that happens in systems engineering.

You have a similar kind of tradeoff if you are looking at using renewable energy. Solar energy is not free energy: The sun comes up and irradiates your collector for free, but you pay for the collector. The more energy your system consumes, the more collector area you need. If you have high energy efficiency in the desalination plant, then you reduce the cost for solar collectors. But at some point, by getting the energy consumption down, you are making the desalination plant larger and larger, so you are paying less for a solar collector, but you are paying more for desalination equipment. Again, there's a tradeoff between the two, and a lot of our focus is on finding the optimum.

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**In your role as director of MIT's water and food initiative, J-WAFS, what do you see as the Institute's contribution to world water security?**

A key question is whether with today's knowledge and technology, we can take another look at our means of obtaining water and come up with approaches that are not so negative environmentally. If we did more with recycling wastewater, for instance, that would reduce the amount of fresh water that needs to be transferred by aqueduct, or pumped out of an aquifer or river. If we could find alternative ways to make plants grow, other than using current chemical fertilizers, we could end the damage done to our waterways by the run-off of those chemicals. If we can find inexpensive and scalable technologies for rural water purification, we improve the health of millions of people in the developing world. If we can make desalination cheap and environmental neutral, we can provide coastal cities with the water they need and give them resilience against droughts, especially in the face of an increasing variable climate. And we can look at how to make agriculture as a whole more water efficient.

And all of these ideas are important in the US, but they all have a worldwide reach. What we'd like to do through J-WAFS is to take the things we're uniquely good at here at MIT and pair

up with people outside who can help us innovate in ways that are effective in and transferrable to other localities – whether overseas or here at home. Water is everybody's problem.

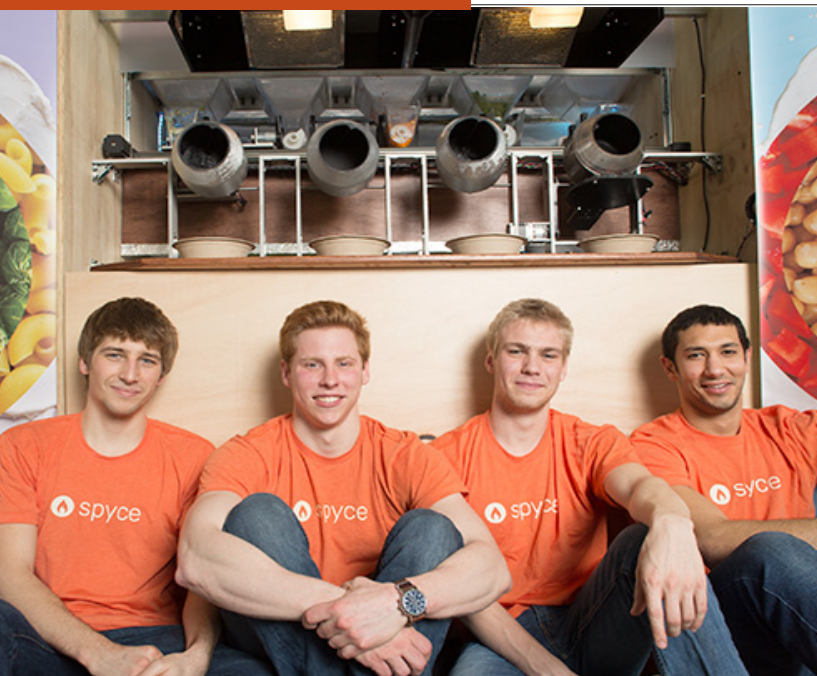
*Abdul Latif Jameel Professor of Water  
John H. Lienhard V is the director of the  
Rohsenow Heat Transfer Lab and the  
director of the Center for Clean Water and  
Clean Energy. In 2014, he also became the  
founding director of the Abdul Latif Jameel  
World Water and Food Security Laboratory.*

*Professor Lienhard earned a BS in thermal  
engineering and an MS in heat transfer  
from the University of California at Los  
Angeles (UCLA), as well as a PhD in fluid  
dynamics from the University of California  
at San Diego. His research is focused on  
desalination and heat and mass transfer. He  
has received a number of awards over the  
course of his career, including a Presidential  
Young Investigator Award from the National  
Science Foundation, an R&D 100 Award,  
the Den Hartog Distinguished Educator  
Award from MIT, the 2012 ASME Technical  
Communities Globalization Medal, and the  
2015 ASME Heat Transfer Award.*

*He is a fellow of ASME, and a member  
of the American Association for the  
Advancement of Science and the  
International Desalination Association,  
among others.*

Coming in the  
next issue:

> Nanotechnology in MechE



Spyce, a team of three MechE undergrads and one grad student – Kale Rogers, Michael Farid, Braden Knight, and Luke Schlueter – won the \$5,000 Audience Choice Award at this year's MIT \$100K Entrepreneurship Competition for their invention of the first fully automated kitchen, which utilizes a tumbler-type machine stocked with raw ingredients to autonomously cook and serve meals in bowls to customers.