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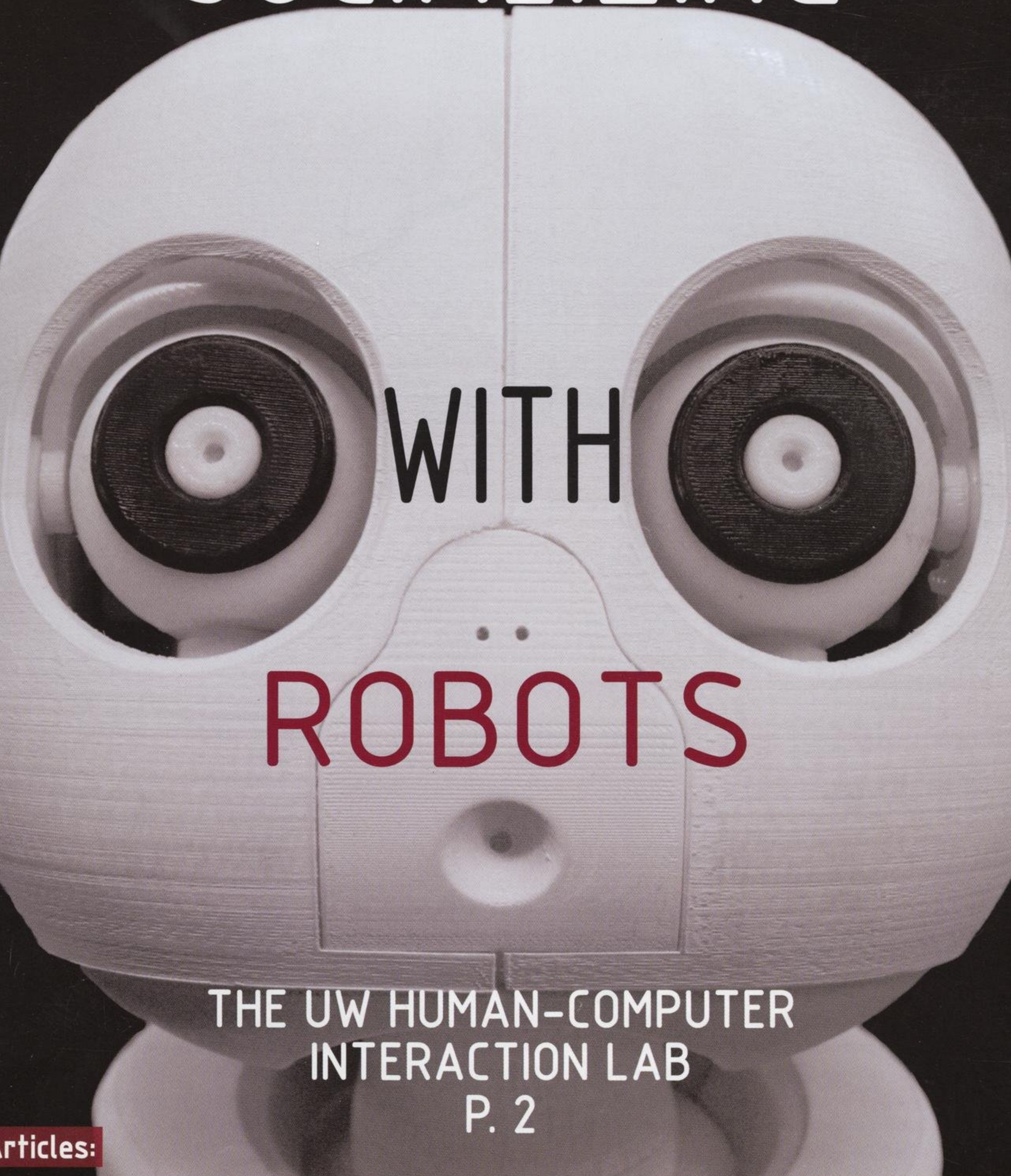
wisconsin engineer

WINTER 2016 VOLUME 121, NUMBER 1

Celebrating 120 Years

SOCIALIZING WITH ROBOTS



THE UW HUMAN-COMPUTER INTERACTION LAB

P. 2

Featured Articles:

College of Engineering
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THE UNIVERSITY of WISCONSIN MADISON

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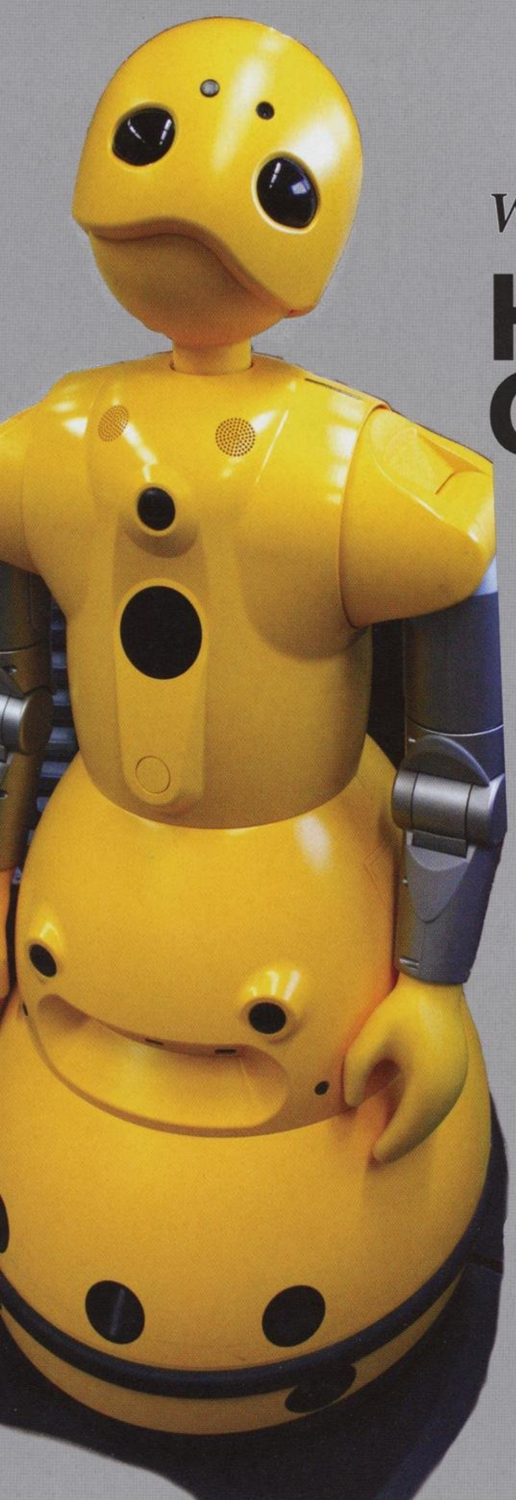
General

COVER:

A friendly robot from UW-Madison's Human-Computer interaction lab says "HI!". Photo: Chris Dupre



Working Together:
HUMANS& COMPUTERS

The Human-Computer Interaction Lab is improving lives by bettering the collaboration between humans and computers

This fun robot is being taught how to teach rudimentary tasks, offering feedback and clarification during research

"It's all about the intangibles" is a classic piece of advice dispensed to job seekers. Career advisors are quick to remind candidates that collaboration, communication, presentation, and personality are just as likely to land them a job as is a staggering list of technical qualifications and experience. Workers heavily favor those they enjoy working alongside, even if those people aren't amazingly fast and accurate. Imagine, then, how difficult it would be to get people to work with you if you only thought about your own programmed goals, spoke in ones and zeros, and were made of cold hard silicon. This is the reality computers and robots face. As their capabilities rapidly expand, one fundamental challenge remains: getting people to like working with them.

The Human Computer Interaction (HCI) Lab at UW-Madison, headed by Professor Bilge Mutlu, is finding ways to bridge the gap between humans and computers. The lab is housed in the computer science department and focuses on researching ways computer science, robotics, design, cognitive science, and social sciences can interact to improve the quality of interactions between humans and computers. The lab's goal is to find ways that computers can collaborate with people to improve their daily lives, rather than just automate tasks. They aren't designing robots that vacuum for you or automatically assemble automobile parts without human help. Instead, they are focusing on researching the principles behind making robots that interact with humans more effective. These principles extend to a wide variety of robots, from those that assist people with disabilities to those that perform automation but require human interaction from time to time, such as a self-driving car.

The HCI Lab's work is inherently multidisciplinary. The team includes members with backgrounds in computer science, engineering, psychology and communication. Danny Wang, a second-year graduate student in the computer sciences department, describes the lab's projects as "comprehensive of all skills." His research on collaboration between the computers in a car and its driver has involved programming, modeling, design, and psychology.

Wang is currently running a simulation in the lab that uses a physical driving simulator and a gaze tracker to evaluate a user's behavior as he or she navigates a virtual city based on Madison. During this drive, objects of interest are circled on the screen, simulating what could be possible on a partially transparent dashboard screen. Wang is working to see how computers alerting drivers to possible dangers and important traffic signals can improve safety. Another component to this research involves making the driving experience better and safer in autonomous vehicles. These vehicles will presumably have the ability to switch between manual and autonomous modes, and the lab is working on ways to make the transitions between those states seamless. "The car and the driver need to share their information during a trip and inform each other about what is going on along the way," Wang says.

Computers are everywhere. Because of this fact and the multidisciplinary nature of the HCI Lab, they are poised to tackle a multitude of challenges, including research on telepresence. Telepresence involves having a remote user control a maneuverable robot that is displaying a real-time video of them. Picture a Skype conference screen on the front of a Segway. This allows a remote participant to maneuver around and talk to people in different rooms and observe different aspects of a project as if they were there.

The lab is also working on robotic devices that analyze a human teammate to anticipate what they will do, and then adapt to the human's needs. The current incarnation of this concept in the lab is a robot arm that hands dishes to a human participant that then washes them. The user gets frustrated if the robot is constantly handing them dishes before they are done drying the previous one but is annoyed if the robot waits until they are done before handing a new dish. The interaction is more enjoyable and effective if the robot mimics what a real human would do by analyzing the movement and body language of the user to determine when they are ready for a new dish and offer it to them in a smooth, human-like manner.

In the past, the lab has also done work on robotic gaze. Eye contact is an essential piece of human interactions, but robots are found to be intimidating and scary if they just stare right at a user. Instead, the lab worked to analyze real human interactions and program the robots to look away at the proper times in an effort to have a more comfortable interaction.

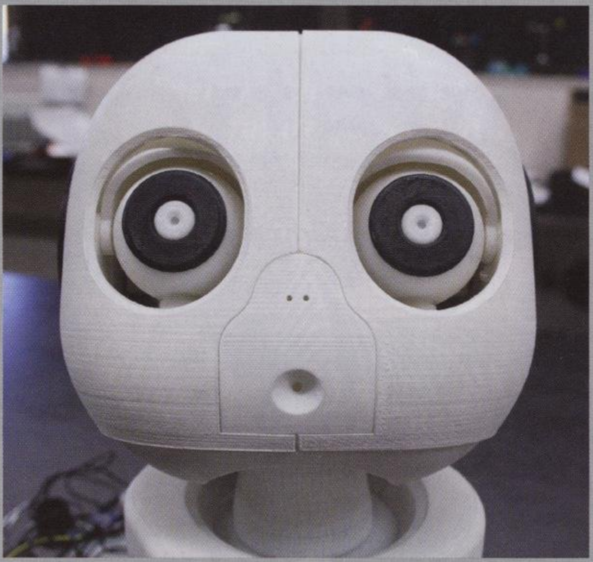
These examples of projects in the HCI Lab highlight its overall goal. The lab is not meant to design incredibly humanlike robots or robots that automate human tasks. Instead, the lab is trying to improve collaborations between humans and robots working together on the same task in an effort to improve people's quality of life. Wang offers smartphones as an example, saying, "The way people interact with a small computer in their hand has changed their behavior completely." Effective collaboration between a user and the computer in his or her smartphone has made a multitude of daily tasks easier and has connected the world as never before. The iPhone is just one example of how effective human-computer interaction can fundamentally change the world. Wang emphasized this, saying "Human-computer interaction can shape our future; it's not just a bunch of algorithms."

Many people fear advances in robotics, artificial intelligence, and automation. However, they often fail to consider the incredible ways collaboration between humans and computers can also advance and ultimately lead to a better human experience. The HCI Lab at UW-Madison is taking important steps to realize that potential.

Written by: Eric Fleming

Photography by: Chris DuPre

Design by: Brooke Berglund



Top: With this white robot, shown above, the lab studies the intersection between programming and human needs to create a seamless blend between human beings and their robotic buddies.

Bottom: The lab is working on software which would work as a liaison between self-driving car's autopilot function and the human driver. The software points out important features to the driver, improving driver awareness.

Inspiring International Innovation

UW students have joined an initiative to teach engineering concepts to students in Japan.

Japan is typically thought of as one of the most technologically advanced societies in the world. However, looking closely at the Japanese schooling system reveals many gaps in the diversity of education. To attempt to address this issue, college students from across the world recently teamed up with a Japan-based organization to provide insight into areas of study that may not be covered in the Japanese school system as well as to provide an opportunity for Japanese students to practice their English skills.

High school in Japan is not mandatory; some students choose to go directly into the workforce, but most students choose to attend a high school where admittance into the schools is very competitive. The high schools in Japan focus on highly specialized departments much like universities in the United States. Additionally, after school and on weekends most Japanese high school students attend cram school to help them stay at the top of their class because of the competitive culture of schooling. The style of education in Japan is textbook-based; students learn in a regimented manner with little focus on creativity or innovative problem-solving.

One program that traveled to Japan in August to work with middle school and high school students was Improv-a-Do!, an organization founded at MIT that focuses on introducing Japanese students to engineering concepts in an informal, fast-paced setting. "I often heard about friends or people commonly stating 'I wish I had time for robotics, but I really couldn't dedicate the huge amounts of time,'" says Ivy Chang, MIT student and Improv-a-Do! co-founder. "Improv-a-Do! was founded to bridge the gap between interest in engineering without a huge time constraint and to help students quickly develop a passion for engineering."

The Improv-a-Do! team was invited to participate in teaching at English camps in Japan alongside Taktopia, an organization that hosts English camps during summer breaks. Taktopia's goal is to expose Japanese students to opportunities that the world offers beyond the islands of Japan. The theme of globalization promoted at the camps encourages students to think critically about the world. The camps are targeted at middle-class Japanese high school and middle school students and expose them to topics not typically included in Japanese curricula, especially liberal arts and engineering. Over the course of the summer 2016 camps, students attended seminars and lectures conducted by the international university students and translated by Japanese university students. The Japanese students were also tasked with designing presentations to demonstrate the concepts they learned at camp to their parents, fellow students, and community members.

At the camps, the Improv-a-Do! staff taught engineering concepts in the realms of problem-solving, engineering design, and product pitching. All of these topics are encompassed in the mission of the Improv-a-Do! organization. "My experience in Japan was very eye-opening. I didn't realize how much creativity is suppressed in Asian countries," Improv-a-Do! co-founder Anu Vajapey says. "Coming from an Asian background, I think it's very important to realize that just doing well on exams is not enough to make someone successful. Being creative and experimenting is key to innovation. By bringing Improv-a-Do! To Japan, we were able to introduce some new concepts to the overworked students there and encourage them to pursue their interest and passions regardless of what the norm is."

By pairing Improv-a-Do!-style challenges with the seminars taught by the team, the summer camps exposed Japanese students to a new way of learning. The hands-on learning style the students learned at camp contrasts greatly with the strictly textbook-based system currently implemented in Japanese schools.

"Improv-a-Do! and the camps allowed the students to really think beyond conformity, and to try something new and not just comfortable."
- Ivy Chang

Currently, Improv-a-Do! is being started at UW-Madison to promote educating engineering concepts by hosting a half-day event where elementary and middle school students can practice innovation and creative problem-solving in a fast-paced environment. Through organizations like Improv-a-Do!, Taktopia, and other groups from around the world, Japanese schools may be able to break away from their traditional education system and begin to promote the innovative thinking which is important for cultivating the world's next generation of scientists and engineers.

Written by: Emily Morzewski

Photography by: Emily Morzewski

Design by: Lindsay George

The True Meaning of Anti-Aging

Recent research on anti-aging focuses on improving elderly life rather than bringing back youth.

Upon hearing the term "anti-aging," people will think of words like "life extension" and "rejuvenation." It's human nature to hope for a longer life span and even more natural to dream of bringing bodies back to youth. As biology and medical research progress, humans explore this natural curiosity on how to extend our life span and develop some anti-aging treatments.

One of the most common anti-aging treatments in our lives are health products, as many anti-aging products also have words like "active" and "improving your body in your middle-age" on their labels. Some typical anti-aging products include UDCA, fish oil, and coenzyme Q10. With all of these options people may ask, "Can these products really bring our cells back to their youthful state again?" According to Dudley Lamming, an assistant professor at UW-Madison researching the biology of aging, most of them don't work. Even worse, as Lamming cites in his paper[1], most of those health products have no relationship with anti-aging at all.

The aging process occurs in the body's mitochondria, our cells' energy dynamos. Descended from bacteria that colonized other cells about 2 billion years ago, they degrade as we age. While they supply our body energy, they also act as a source of reactive oxygen species (ROS) and finally lead to mitochondrial DNA (mtDNA) mutations, which are often observed in the human body[2]. In other words, if humans find a way to slow down the process of mitochondria, we might find a way to stop aging.

In a study by David Sinclair, a professor in the department of genetics and co-director of the Paul F. Glenn Center for the Biology of Aging at Harvard Medical School, the compound nicotinamide adenine dinucleotide (NAD) was found to increase the vitality of mitochondria. After being injected with NMN (nicotinamide mononucleotide), a chemical found naturally in the human body to boost the NAD level, the muscles of elderly mice were returned to a youthful state after just one week of injections. However, there is still no direct clinical proof that the treatment reduces aging.

"Scientists may find a way to cure some age-related diseases in near future, but returning to youth and extending our life span is still a far-off goal for humans."

Currently in Madison, Lamming's work is mainly focused on a protein kinase called rapamycin (mTOR). Rapamycin was first introduced as an anti-cancer drug, but it showed potential as an anti-aging substance. The Lamming laboratory pays attention to understanding the physiological role of rapamycin (mTOR). Rapamycin, an inhibitor of mTOR, can improve the health and life span of many mammals, including humans. Dr. Lamming's recent review article explains that Rapalogs and mTOR inhibitors can be treated as anti-aging therapeutics[3]. This substance gives implication about many age-related diseases like diabetes, Alzheimer's disease, and cancer. In their research process, Lamming's group found that sometimes the injection of rapamycin causes many side effects. Afterwards, Lamming and colleagues find out that low doses will lower the possibility of showing side effects.

In reality, neither the NAD booster nor rapamycin drugs have been tested in human trials. Most of their effects are only shown in mammals like dogs or mice. Possible side effects or risks are still unknown. Also, further evidence is required to show its anti-aging effects. Of the NMN example above, Lamming explains, "The function of the muscle does improve, but this does not mean the behavior of the muscle system goes back to the youth state."

According to Lamming, the word "anti-aging" does not precisely define his current work. Nowadays, scientific work on anti-aging therapy is not defined by what people would regard as anti-aging; it is not as simple as that. Today, anti-aging therapy mainly focuses on how to make people live longer and healthier. Scientists hope to decrease the pain and diseases that occur when people reach their 70s and 80s. It is not only about extending our life span, but also improving quality of people's lives in their old age. Scientists may find a way to cure some age-related diseases in near future, but returning to youth and extending our life span is still a far-off goal for humans. Although there are some findings that give us insight on how to truly solve our aging problems, more research and more testing will be required to determine whether anything is qualified as having a truly "anti-aging" functionality.

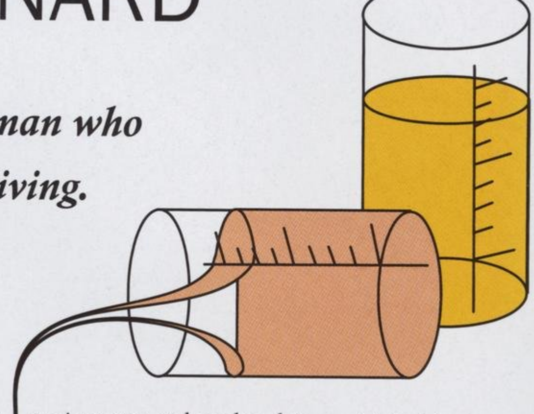
Written by: Yinghong Liu

Design by: Marvyn Hsu

1. Longer lifespan in male mice treated with a weakly estrogenic agonist, an antioxidant, an α-glucosidase inhibitor or a Nrf2-inducer
2. Payne, & Chinnery. (2015). Mitochondrial dysfunction in aging: Much progress but many unresolved questions. BBA - Bioenergetics, 1847(11), 1347-1353.
3. https://www.medicine.wisc.edu/people-search/people/staff/4646/Lamming_Dudley

Faculty Profile: Jim Maynard

Getting to know the man who blows stuff up for a living.



Explosions, cryogenic temperatures, and dangerous chemicals may all seem extraordinary, but to one man in particular, they're all just part of another day on the job. Jim Maynard, Senior Instructional Specialist for the department of chemistry, has been conducting lecture demonstrations at UW-Madison for the past 15 years. Over the course of his academic career, he has inspired tens of thousands of students through his fascinating yet equally educational experiments, and he has unquestionably become one of the most welcome faces in any chemistry lecture hall. Maynard's casual confidence with chemicals makes it seem like he's been doing chemistry for his entire life, so it may come as a surprise that he didn't decide to pursue chemistry professionally until later in life.

As a member of the United States military, Maynard spent years stationed aboard a submarine and cites this as a key experience where he learned to deal with stress, something that is also very prevalent in his current role. "When you're a professor and have to get something done, you have a year. When I have to hurry up and get something done, I have three minutes," he says. After retiring from the military, Maynard enrolled at UW-Madison in 1995 as an adult student, initially planning on studying physics. It wasn't until his junior year that he decided upon chemistry and soon after graduating was hired to replace the old lecture demonstrator.

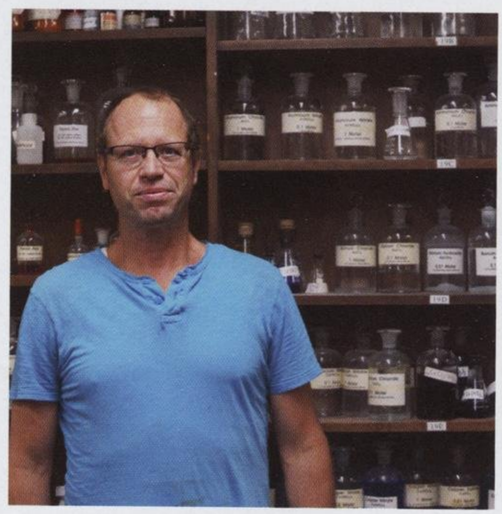
Now conducting over 3,000 lecture demonstrations per year, Maynard is able to expose nearly 40 percent of undergraduates (approximately 12,000 students) to many of the intricacies surrounding the central science. Whether conducting long-time personal favorite demos like the levitating superconducting magnet or completely new ones such as an air-free polymerization reaction that he himself devised, he always brings an unparalleled level of enthusiasm which can spark interest in even the most apathetic of students. "It's an opportunity to observe some science without taking notes, where you just see and hear what's going on," says Maynard. "It puts the course in perspective and shows where science fits in the real world, and I think that that's really valuable." While on the surface these demonstrations may simply seem like a welcome break from the stress of a fast-paced lecture, they serve a critical role in reinforcing key concepts and facilitate learning in valuable ways.

One approach in which Maynard accomplishes this is by incorporating household items like tonic water or laundry detergent into his demonstrations, "because if you can link your own experiences to chemistry, it'll help you remember it better," he says. As beneficial as this is, many students don't realize how lucky they are to have such a talented resource supplementing their learning. There are less than 150 lecture demonstrators remaining in the U.S., and that number is rapidly decreasing. Many universities across the country choose to allocate their budget resources elsewhere or are otherwise unwilling to assume the risk of liability that comes with having professional lecture demonstrations. Fortunately, UW-Madison is not currently one of them and students will be enjoying Maynard's talents for years to come.

Written by: Stephen Schwartz

Photography by: Therese Besser

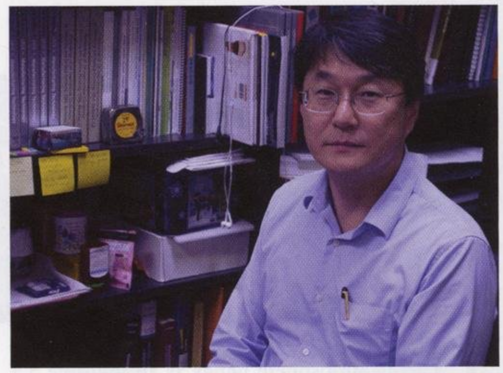
Design by: Patricia Stan



"It puts the course in perspective and shows where science fits in the real world, and I think that that's really valuable." – Jim Maynard

Engineering for Precision

A UW engineering professor holds the keys to one of the only nano-precision milling machines in North America.

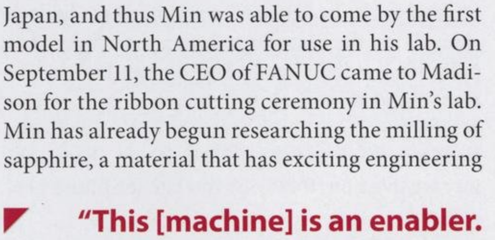


Dr. Sangkee Min

In the basement of the Mechanical Engineering building resides one of the most advanced manufacturing devices in existence. Created by FANUC, a robotics company headquartered in Japan, the ROBONANO α-0iB is a state-of-the-art milling machine. Any milling machine, typically computer controlled, is capable of drilling, cutting, and etching on a 3-D axis. However, the ROBONANO is designed to achieve a level of precision far smaller than standard machines - down to a single nanometer, or one billionth (1×10^{-9}) of a meter. For scale, your fingernails grow at about one nanometer per second.

This incredible machine has been acquired on a two-year renewable loan by Dr. Sangkee Min, assistant professor of mechanical engineering. Min earned his PhD at UC-Berkeley and traveled to Japan for postdoctoral work, where he developed a relationship with several Japanese corporations, including FANUC. The ROBONANO has been in development in Japan for over a decade, but it has been highly export controlled. Recently, FANUC obtained a license to sell the machine outside of Japan, and thus Min was able to come by the first model in North America for use in his lab. On September 11, the CEO of FANUC came to Madison for the ribbon cutting ceremony in Min's lab. Min has already begun researching the milling of sapphire, a material that has exciting engineering applications when it can be so precisely machined with technology such as the ROBONANO.

> **"This [machine] is an enabler. Manufacturing for design gives ultimate freedom to the designer."**
> **– Dr. Sangkee Min**



The ROBONANO without any attachments. The parts attach on to the circular bases pictured, allowing for extreme precision milling.

The ROBONANO is able to maintain nanometer precision through a carefully designed method of reducing friction of bearings to near zero. Since friction builds up measurement error after long periods of machining with frequent stopping and starting, neutralizing it is a necessity. The position of the spindle (the cutting tool made of diamond) is adjusted on a 5-axis air bearing with an angular precision of 0.000001°, which means the piece being machined is effectively floating on air above a table, much like a bullet train magnetically levitates above its track.

Movement during a cutting pass is measured with laser beams on a glass scale spaced only tens of picometers (a trillionth of a meter) apart, so the position of the spindle and the material being worked on are always known in the machine's coordinate system within one nanometer. External disturbances are a major concern, as any vibrations will cause a decrease in precision. Therefore, the ROBONANO is housed on a slab of concrete on top of bedrock and separated from the rest of the building by a rubber shock-absorbing caulk. Min even wants to set up sensors that detect when the train will be passing by on the tracks in front of the mechanical engineering building so they can plan accordingly and avoid excess vibration.

One of the main benefits of fabrication with such high precision is the ability to take advantage of unique material properties. A block of metal, for example, is made up of tiny grains, similar to wood. A cutting stroke against the grain will yield a worse finish than going with the grain – this is no surprise. However, each grain is composed of many even smaller crystalline structures of metal. The ROBONANO makes it possible to machine these individual crystals at the nanometer scale. This can produce a surface finish much finer than ever thought possible, which can result in extremely smooth, reflective, or even iridescent surfaces. Other materials that are typically very brittle can also be machined much more easily; as Min says, with the ROBONANO "Theoretically you can machine anything." This is because the nano-milling procedure is almost surgical; it has very fine control and will not subject the material to intense forces that could break it. In fact, there are even biomedical applications that use the ROBONANO to etch an extracellular environment conducive to cell growth in certain patterns.

Min's primary research right now deals with synthetic sapphire, an emerging material with unique properties at the nanometer scale. Sapphire is not ordinarily considered an "engineering material," as Min describes. In order to be an engineering material, it must be abundant, cheap, and able to be manufactured on a large scale. According to Min, "Sapphire is not abundant, it is expensive, and it is not manufacturable, so it did not meet any of the requirements. But now it can be synthesized." Synthesizing sapphire makes it easier to obtain, but the ROBONANO is still needed to machine it due to its fragile properties. Its uses could range from consumer electronics and optics to national defense, where it has already been incorporated into the nose-cones of infrared guided missiles. Once Min develops an effective technique to machine sapphire, he wants to move on to even more brittle materials like ceramics.

Dr. Min's goal with the ROBONANO is to reverse the usual design for manufacturing paradigm. Certain designs simply cannot be fabricated and must undergo several iterations before being manufactured on a large scale. It limits engineers, causes long delays, and results in the product losing some of the functionality of its original design. A manufacturing for design mentality makes anything possible to create, and the ROBONANO opens up infinite possibilities. The goal is to allow for any design to be manufactured by using the most cutting-edge machines known to science and developing the process into something scalable. "This [machine] is an enabler. Manufacturing for design gives ultimate freedom to the designer," Min says. "If something is not manufacturable, it becomes a research project. This allows academy and industry to walk together and overcome challenges." The ROBONANO high-precision milling machine will soon lead to more advanced solutions to engineering problems around the world. W/E

Written by: Edwin Neumann

Photography by: Alexander Fanner

Design by: James Johnston

air pollution:
a silent killer

New research shows pollution is causing more damage than previously believed.

Earth's atmosphere hangs as an invisible 5.5 quadrillion ton weight over the entire 196.9 million square mile surface of the planet. In comparison to those numbers, it is hard to imagine that our everyday actions could result in significant atmospheric change. Today, the degree to which human activity has impacted global atmospheric conditions is heavily debated in American politics, but it is time to put an end to the debate. Professor James Jay Schauer of the Department of Civil and Environmental Engineering at UW Madison weighs in on the discourse by noting, "There is no point in trying to assign blame anymore... we have to accept that air pollution is a problem." Regardless of the cause, it has become clear that the incomprehensively massive ocean of air we breathe every day is not just beginning to change – it already has. But what does "air pollution" include and how can we define it?

"There is no point in assigning blame anymore… we have to accept that air pollution is a problem" – Dr. Schauer

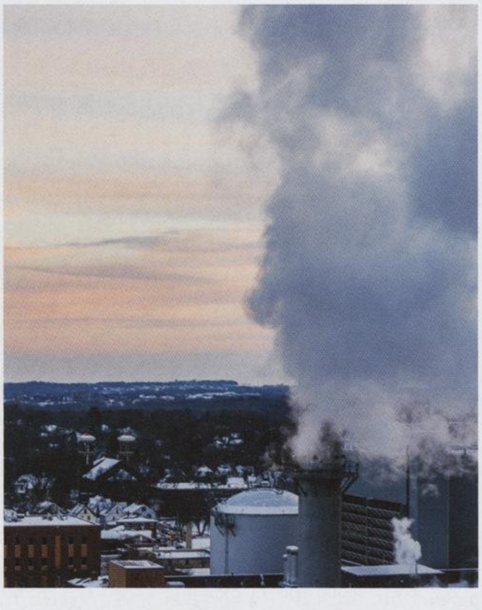
At UW-Madison, Schauer researches chemical methods of quantitatively tracking air pollution. These methods have been implemented in Europe, Asia, and the Middle East to measure the impact of airborne pollutants on the climate and human health. Global data collection efforts have revealed that pollution profiles and effects can vary drastically from country to country. Air pollution becomes even more complex on a regional scale when considering the effects of pollution sources such as roadways and industrial processes. Because of the complexity, Schauer explains the solution for air pollution is not "a one-size-fits-all" approach. In order to approach this problem, a good start is breaking down pollution into two separate issues: the global effects on the climate and the local effects on human health.

Scientists have argued for years over climate change and our ability to cause or reverse it. Unfortunately, it is impossible to conduct scientific climate change experiments on a global scale and over a meaningful time span. This means no one can prove climate change is happening as a result of air pollution. On the other hand, research being done by Schauer and others in his field has proved something else – regardless of the cause, the atmosphere and the climate are changing.

The composition of the atmosphere has changed more in the last 100 years than it has in the last few million years. As of the last week in September 2016, carbon dioxide levels on Earth will likely not drop below 400 ppm for a very long time, possibly hundreds of years. While 400 ppm (a concentration of 0.04 percent) does not sound significant, it is the latest in a long list of milestones feared by climate change experts. Even though 0.04 percent is not enough to cause serious damage today, "If we do not change the way we do things, levels of CO2 will rise high enough to leave some areas of the world uninhabitable," Schauer says. While it is unlikely that we will ever encounter the skyscraper-sized tidal waves and "super storms" portrayed in movies like "The Day After Tomorrow" or "2012," there soon may be areas of the planet too polluted to support human life.

Air pollution has a bigger impact on human health than most people realize. Out of all major pollutants (such as greenhouse gases, ozone, and industrial byproducts), particulate matter is the most harmful to humans. It is difficult to measure the exact health impact of air pollution because it does not cause any immediate symptoms. Instead air pollution acts as a silent killer, slowly shortening life spans over the course of decades. Recent data supports this claim and estimates that in developing regions with high levels of aerosolized particulate, "One out of every five to ten deaths is partially due to, or prematurely caused by, the effects of air pollution," Schauer says. The obvious solution is to remove local sources of particulate matter, but as always with air pollution, the problem is more complicated than that. Sometimes, methods of reducing particulate matter result in the production of pollutants that negatively affect the global climate and human health in other ways.

Luckily, countries around the world are making an effort to reduce air pollution. The United States has invested billions in clean energy technologies, but the rest of the world is taking a different approach. Rather than holding onto a wasteful and destructive way of life, "communities in Europe and Asia are changing the way they live," Schauer says, while



still exploring the long-term solution of renewable energy. Europe does this by raising air quality standards and transitioning to pedestrian-friendly communities. Asia is attempting to lower pollution levels by restructuring its transportation industry to include public transit and limiting its use of fossil fuels. In Schauer's opinion, these lifestyle changes are the best way to lessen the effects of air pollution on the climate and human health. The most important thing to remember is that "Our actions today will shape that atmosphere centuries from now," Schauer says. If we do not change the way we live now, it may be too late for future generations.

Air pollution, along with climate change and other environmental concerns, could be the most urgent societal challenge we will face this century. Today, air pollution is rapidly changing the global climate and negatively impacting health in certain regions. This is not a problem that will just go away if ignored. At the current rate, the future impact of pollution will be even more severe and on a wider scale. It is time to stop arguing about air pollution, climate change and the environment so we can find a solution.

Written by: Tom Eithun

Photography by: Ben Chen

Design by: Tim Campbell

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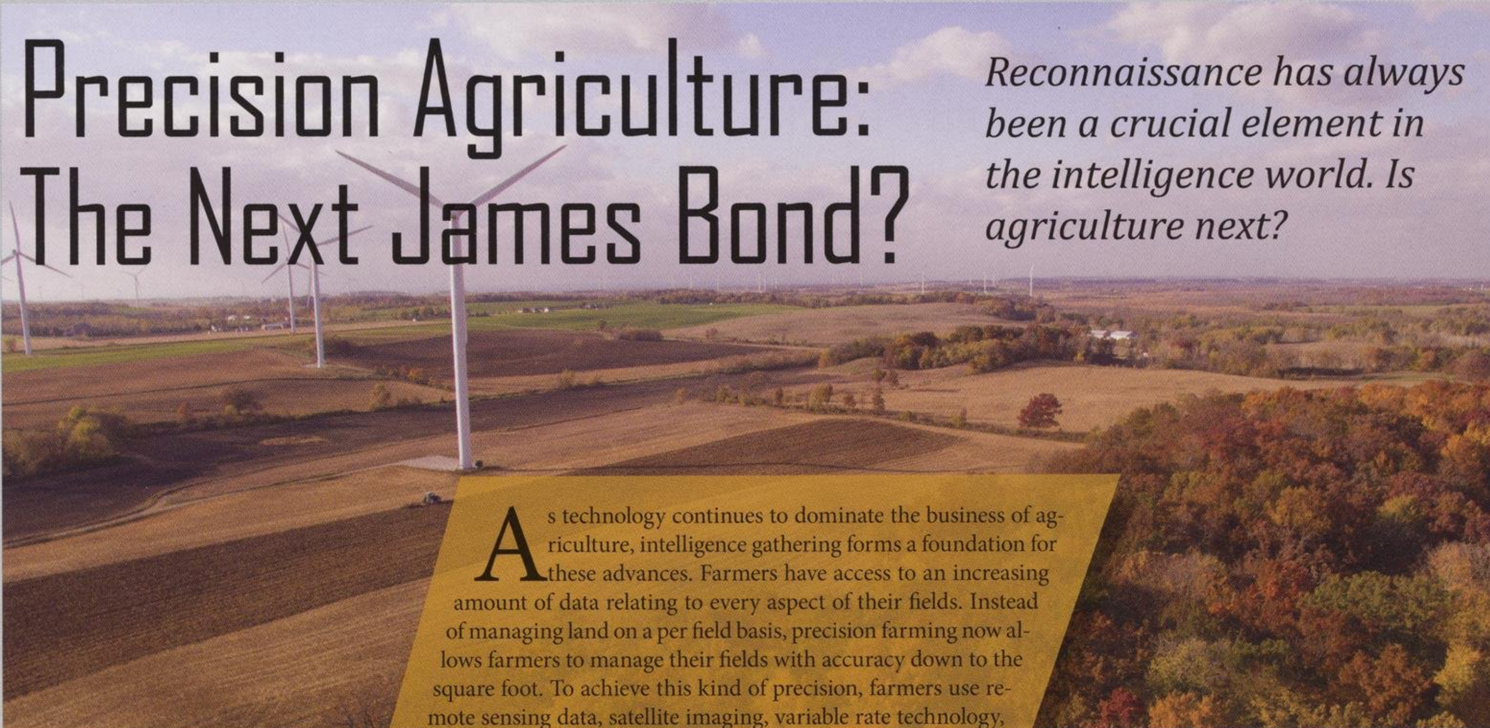
Precision Agriculture: The Next James Bond?

Reconnaissance has always been a crucial element in the intelligence world. Is agriculture next?



As technology continues to dominate the business of agriculture, intelligence gathering forms a foundation for these advances. Farmers have access to an increasing amount of data relating to every aspect of their fields. Instead of managing land on a per field basis, precision farming now allows farmers to manage their fields with accuracy down to the square foot. To achieve this kind of precision, farmers use remote sensing data, satellite imaging, variable rate technology, and drones (or unmanned aircraft vehicles). The result? James Bond meets Barnyard.

The Benefits

Brian Luck, an assistant professor and extension specialist in the UW-Madison department of biological systems engineering, deals with precision agriculture on a daily basis. Essentially, precision farming is site-specific management. Today, farmers have both the equipment and the manpower to micromanage their fields in order to more efficiently and effectively oversee their croplands. "Different areas of the field are being treated differently with inputs, so the end goal is to manage on a smaller area to minimize input and optimize, or maximize, profit," Luck says. Essentially, the farmer uses less input—herbicides, pesticides, water, etc.—to make the most profit. It's an issue of input and resource allocation for either maintaining yields or using the land optimally.

Yet maximization of farmers' profits isn't the only benefit of precision agriculture. This technology can also reduce the negative impacts of farming on the environment. Over-application of chemicals is the main cause of agriculture's environmental repercussions. This problem can be combatted by using the tools of precision farming, Luck explains. Instead of applying chemicals consistently across an entire field, growers can specifically target areas of need within their fields and apply the right amounts of chemicals where and when they are needed, saving both time and money and minimizing environmental impact. The same idea can be applied to water conservation. As humans are increasingly exploiting springs, rivers, and lakes across the world, the need to conserve water grows. Irrigation in many parts of the world can be both difficult and expensive, and it is all too easy to over-irrigate, wasting precious time, money, and water. By obtaining more detailed information with precision technology, farmers can precisely compute how much water each plant requires.

How it Works

The basic concept behind precision agriculture is as each individual plant grows, it will react differently to the same growing conditions and therefore will develop different needs than neighboring plants. The plants take in sunlight, nutrients from the soil, and water. Based upon this, GPS imaging, drones, and remote sensors can detect physical properties of each plant, which a producer can use to determine the plant's needs. From this information, the farmer can individually cater to each plant's needs.

Take irrigation for example. As plants grow, incoming sunlight is either reflected or absorbed through their leaves and then used for photosynthesis or converted into heat. Similar to the way people perspire to cool off, healthy plants "transpire" to keep cool under the heat of the sun; they release heat through tiny pores on their leaves that open to allow water droplets to evaporate. But a plant that is under stress does not transpire well, starts to overheat, and begins wither and change its texture, shape, and color. Remote sensors can measure the temperature of plants, or to be more precise, they can measure how much energy plants emit at thermal infrared wavelengths. The plants' temperatures can then be used to determine just how much water the plants are using by relating water intake to the surrounding air temperature. If farmers are getting accurate and timely measurements of plant and air temperature from their remote sensors, then they can program exactly when and how much water to give each crop through an irrigation system. This is just one application of precision farming; many other plant attributes can be measured to indicate which variables – such as photosynthetic activity or soil moisture – are changing over time and by how much.

The Gadgets

There are quite a few gadgets that make all of this possible. Precision farming found a legitimate foothold with the establishment of Global Positioning System (GPS). At that time, accuracy of the imaging was within plus or minus a couple of meters, according to Luck. Today, Real-Time Kinematic (RTK) satellite navigation brings that error down to plus or minus a few centimeters. Along with better satellite imagery came resolution improvement of application equipment, such as planters and spreaders. "While we aren't quite there yet, we can theoretically tell you the location of every seed in every field based on the accuracy of our equipment," says Luck. That might even be more impressive than anything James Bond can do.

Unmanned aerial vehicles (UAVs), too, are key tools in the recon arsenal of the precision farmer. Drones are the scouting tools; they let growers know when something is wrong. Information gathered from drones can be used to mark areas of a field that seem problematic (i.e. more yellow than others), allowing for targeted checks in the field that may reveal a problem with insects, nitrogen shortages, or lack of water. Whatever the issue, treatment can then be focused to the problematic area instead of applied to the whole field.

The most crucial instrument to the success of precision farming is the variable rate technology now being used on farming equipment. These technologies can be programmed to control the dispersion of chemicals, water, seeds, etc. based upon the data collected from satellite imaging, drones, and remote sensors— all of the reconnaissance work.

Go Big or Go Home?

A controversial topic surrounding precision farming is its impact on the family farm. Is precision farming helping to bring about a decline in small-scale farming operations? During the infancy of its development, this tech was only benefitting big industry due to initial cost. However, it has come to a point where small-scale farming operations can reap the rewards of this technology, too. With the dropping equipment prices, it is now becoming economically feasible for the family farm to implement precision farming technology as well. Imaging costs can be shared between growers with multiple-field images, lessening the burden of investing in precision agriculture, and remote sensing technology is dropping in price as well. It is advantageous to all producers to have more information, both in quantity and quality, about their crops.

With agriculture entering into the big data trend of the 21st century, farmers are expected to know seeding rates, soil fertility, yields, planting data, chemical data, and more about their croplands—years' worth of data. With this information, farmers can seek out crop consultants to determine how best to optimize their resources to get the most bang for their buck. As Luck puts it,

"We know exactly, on average, what we need to put into the field to get the maximum amount of yield with the least amount of cost. Who wouldn't want to do that?"

Future Outlook

Looking to the future, the next step for precision farming is to integrate these reconnaissance techniques with automated solutions to the problems they expose. Traditionally, farmers have been out in the field, in the barns, running their operations firsthand. Only in recent years has the dairy industry been moving to a more automated system with technology like robotic milking. Now, crop production is heading that way as well. The company Case IH has recently come out with a fully autonomous concept agricultural vehicle as novel and high-tech as James Bond's Aston Martin. Without a cab, or even a steering wheel, it is a revolutionary idea in the world of agriculture. Unlike a person, "it won't get tired, and all it needs is fuel," Luck points out. This means producers can harvest for 72 hours straight if need be. He goes on to explain, "We're able to make the most of narrow harvest windows for optimal crop harvest and crop quality," and so the timing of planting and harvesting can be perfected to get the best crop possible.

Because agriculture machines are becoming more automated, the newest concept designs for them are actually becoming smaller to improve safety. With lower costs, these smaller automated vehicles are safer, more affordable, and more easily serviceable. "The next big leap," Luck says, "is going to be autonomous, and it's going to be swarm-type farming: Multiple smaller machines doing multiple tasks in the same field."

Because of this marriage of big data with variable rate technologies, growers are no longer limited to treating fields as a homogenous unit. More information is leading to optimizing every part of the crop industry: targeting problem areas, reducing inputs, and perfecting planting and harvest times. This means less cost, more energy savings, and even more profit: it's a win, win, win situation. Beat that, James Bond.

Written by: Morgan Adkins
Photography by: Dylan Guelig
Design by: Suzanne Kukec

Reaching for Mars

Elon Musk's plans to reach Mars generate new public interest in space travel.

When the film "The Martian" opened in theaters last year and became a blockbuster success, an age-old dream of traveling to Mars shared by millions across the world was reawakened with vigor. However, few people are aware of just how close to reality this trip to Mars might be. One of those few is Elon Musk, founder and CEO of SpaceX (among his many other ventures). Started in 2002, SpaceX's long-term goal has always been reaching Mars. It is Musk's hope that SpaceX will do with space travel what Steve Job's iPhone did with smartphones: take a fairly unexplored idea and make it a normal, even essential, part of our lives. On Sept. 27 at the International Astronautical Congress, Musk announced his official grand plan, called the Interplanetary Transport System (ITS), for traveling to Mars and eventually setting up a permanent colony.

Of course, there are countless challenges even outside of the technical design of the spaceship itself that must be overcome before travel to Mars becomes a reality. Some of the biggest issues are the effects of cosmic radiation, the biological effects of lessened gravity on the human body, survival on Mars, and, perhaps most importantly, acquiring funding.

Aaron Olson is a graduate fellow at the UW-Madison Fusion Technology Institute who was in the audience for Musk's ITS announcement. Olson is optimistic that we can work out these technicalities, explaining that plans to go to Mars have been tossed around for decades but before Musk, none gained any real traction. This is why Olson believes that "the important thing is that [Musk] is getting this kind of thinking into the mainstream."

In fact, SpaceX's plans have already prompted one of the biggest players in the aerospace industry, Boeing, to announce their goal to beat SpaceX at their own game and get to Mars first. This kind of space race competition is probably great news, explains Olson, since people have been thinking about this for a long time, "but I think the scope and grandeur with which they lay out their plans might change based on what Musk did."

According to Musk, this trip to Mars will start by launching a spaceship carrying over 100 passengers into a brief orbit around Earth. After reaching orbit, the shuttle will be fueled up for its three-month journey to Mars. Next, the ship will leave its orbit of Earth and make the journey through deep space, powered primarily by deployable solar arrays with gas boosters for steering.

Once on Mars, Musk says the passengers will disembark and begin the process of setting up a colony. The ship will be powered by an oxygen-methane propellant system so that the fuel can be harvested from the abundant ice on Mars and the gases in the atmosphere. Due to this necessity, at least some of the earliest explorers will have to begin the process of acquiring those resources. Once this is accomplished, the refueled ship will launch from Mars and return to Earth to be outfitted with the next set of space-faring passengers. Musk envisions that eventually over 1,000 ships will be performing this cycle, ultimately leading to a permanent colony of 1 million people on Mars.

> **"There's always that sense of pushing the envelope, undertaking large adventures, and being a pioneering sort of society."**
>
> **– Aaron Olson**

Progress is being made on the funding side as well, as much has been made of SpaceX's recent successes in landing reusable rocket boosters back on Earth after launch. The ITS will be an enormously expensive project, coming in at an estimated $10 billion, so the ability to reuse not only rocket boosters but every component of the system is of paramount importance in keeping the plan even remotely affordable. The reason multiple uses help lower the expense so much is that a major cost of missions to space today, like the Mars Curiosity Rover, stems from the fact that the whole project only has a one-time use. All of the money that went into planning the mission, building the ship, and developing other necessary equipment must be repeated for each new mission.

To address this, the ultimate goal Musk has set is to have his reusable system reduce the cost of a trip to Mars to about $200,000 per person. He hopes this will entice enough people to participate for the program to turn a profit. Despite Musk's optimism, it remains to be seen whether SpaceX will be able to reach that goal, and there is much debate among experts regarding the feasibility of Musk's predictions.

However, even with all of the obstacles that stand in the way of a modern day Neil Armstrong stepping onto the surface of Mars, we still seem to have an inexhaustible desire to reach our red neighbor. SpaceX is the first private company to seriously consider accomplishing this goal, but now that Musk has opened the door who knows what comes next?

Olson points out that for humans as a species, "there's always that sense of pushing the envelope, undertaking large adventures, and being a pioneering sort of society," so it's only natural that we now look to the next frontier. Whether it be for the sake of this purely adventurous spirit or for more calculated goals of scientific research and human preservation, it can certainly be a good thing to keep extending the reach of our species into a new era of discovery. W/E

Written by: Ben Zastrow
Photography by: Shashank Agrawal
Design by: Suzanne Kukec

The Impossible Just Got Possible

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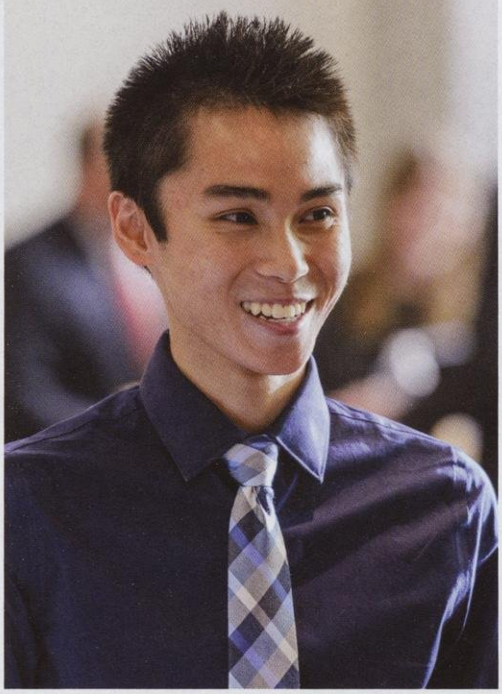
A UW-Madison student scientifically debunks the idiom "You Can't Un-ring a Bell."



Chris Nyguen beams during the UW Madison presentation ceremony of the GE Unimpossible award.

"You can't un-ring a bell." This is something that grandparents and parents often tell kids, teaching them to be careful with actions and words because they can't be undone. However, this age-old idiom may not be true; perhaps a bell can be "un-rung."

In fall 2015, General Electric (GE) held an "Unimpossible Missions" competition among the engineers who worked there. The competition's goal is to take a given idiom and engineer a way to prove the idiom wrong. Several of the idioms that the GE engineers worked on were "A snowball's chance in hell," "Talking to a wall," and "Can't catch lightning in a bottle." Later, GE made a University Edition, challenging students from all over the world to come up with an idiom and prove it wrong using GE technology and scientific reasoning.

Chris Nguyen, a biomedical engineering major at UW-Madison, won first place in this worldwide competition for his conceptual proof of how to un-ring a bell. Although originally studying to graduate with a psychology major, a physics class in the second semester of his freshman year inspired Nguyen to switch into engineering. Growing up across the street from one of GE's largest health care locations, Nguyen had been curious about GE for some time. When he learned of the competition, Nguyen was eager to compete.

Nguyen explains that to un-ring a bell, you'll have to "measure the sound wave that comes into the headphones from the ring, and then flip that sound wave upside down, play it out again into the headphones, and it will cancel the noise." Nguyen's proposal included an insulated room lined with non-acoustic foam. The foam is critical for the experiment because without it, the sound waves will echo and bounce off of walls and surfaces, eventually making it to the microphone. The foam makes it easier to control and record the amplitude and frequency of the sound waves coming from the bell. Nguyen concluded that with GE's sub-sea conditioned monitoring system, a microphone that measures vibrations in the deep ocean, he can capture and measure the ring of the bell. Then he proposed to use destructive interference with the inverse sound of the bell to cancel the sound altogether.

Most of Nguyen's research went into finding the perfect idiom to debunk for the GE un-impossible mission, saying it took him 20-30 hours. The proposal itself only took him about five hours. The struggle with the proposal, he described, was that it was due during finals week. So, he admits that he felt a little guilty prioritizing his proposal over his exams but believes it was worth the prize.

The reward for first place in the GE Unimpossible Missions competition includes a ten-week internship at the GE global research center in New York. Nguyen will also receive a scholarship of up to $100,000 to attend graduate school. In addition, GE will make a video of the idiom, showing the un-ringing of a one-ton bell. The second place winner received a ten-week internship as well for the contestant's "hanging by a thread" proposal. This idea included using a very thin string of a polymer developed by GE to hang an airplane at the end of it. In theory, the plane will be suspended off the ground by this slim but strong polymer. The third finalist, a student from a university in India, will not receive a prize but chose the idiom, "You can't make rain go up." Nguyen comments that he "wished [he had] thought of that one." He explains that the Indian student's proposal included manipulating the dipole moments within the water using a strong magnetic field, forcing the water droplets to move in the opposite direction. In fact, there is a research team at UW-Madison working on how to manipulate and control the movement of water.

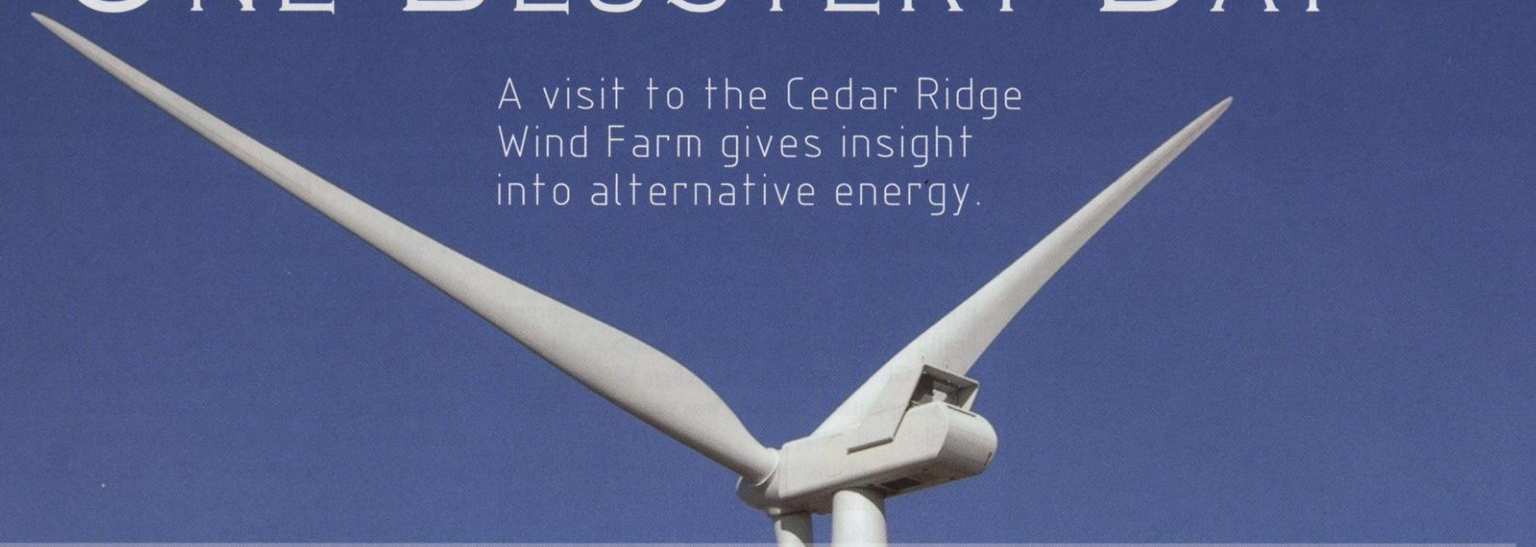
In the coming years, Nguyen plans on continuing his studies in biomedical engineering, with an emphasis on instrumentation. He aims to better the medical field by developing robotic tools that will aid doctors in surgeries. Meanwhile, the GE Unimpossible Missions: University Edition will continue to cleverly engage engineering students around the world to challenge themselves and to think beyond the impossible.

W/E

Written by: Nena Nakum
Photography by: Bryce Richter
Design by: Sadeq Hashemi

Chancellor Rebecca Blank and Dean Ian Robertson came out to congratulate Chris at the UW Madison presentation of Chris' GE Unimpossible award and scholarship.

ONE BLUSTERY DAY



A visit to the Cedar Ridge Wind Farm gives insight into alternative energy.

The bus rumbled along, going up and down through the hilly farmland of Wisconsin before finally coming to a stop outside a small, unassuming building. For all intents and purposes, the structure was not worth noticing. It was small, brown, simple. But it was also surrounded by wind turbines.

The wind was gusty that day and the white blades of the turbines were spinning merrily in the vista. The wind turbines themselves were spread throughout the countryside to the point where they became part of it. As I would later find out, they were spread out that way to prevent the turbulence produced by one wind turbine from affecting the operation of any others. But in the moment, when I first stepped off the bus, all I saw was peacefully spinning wind turbines scattered throughout the countryside.

Once I got off the bus with my tour group, we were welcomed into the small main building and shown to a small presentation room where we learned about Cedar Ridge Wind Farm and how the towers worked. Each tower is 262 feet tall. At the top of each tower are three blades that spin, causing the turbine to spin and generate electricity. The turbine and generator are both located at the top of the tower. All of the electricity generation happens at the top of the tower, and then the electricity is simply wired down the tower and into the ground, where it is sent into the collection and distribution systems.

First, the electricity generated from each turbine is collected, meaning that all the power from the wind turbines is sent to the substation. The substation's main purpose is to amplify the voltage of the electricity and set it to the right frequency so that it can successfully be sent down the transmission line. Without the substation, the electricity generated would only be of use to people living in the immediate vicinity of the wind farm.

Interestingly, the turbine is only functional for a certain range of wind speeds. At the low end, the wind must be blowing at least eight miles per hour in order for the turbine to be useful. At the high end, the wind cannot be blowing 45 mph or higher or else the rotor of the turbine might be damaged. When the wind is blowing faster than is good for the rotor, the blades of the wind turbine are "pitched," or turned 90 degrees so that wind is no longer pushing on the blades. Instead the blades are slicing through the wind which blows right by.

After the presentation, we each put on a safety helmet and glasses and went outside for a closer view of the wind turbines. The wind was still blowing strongly and the turbines were spinning at a good pace, but they didn't make a sound. It was incredibly peaceful as we walked up a steep hill to the closest wind turbine. At about five or ten feet away from the tower, a faint hum could sometimes be heard. It was barely noticeable, but it was a reminder of how fast the blades of the turbine were spinning and of how much power it was generating at about 1.65 megawatts on a windy day like that one.

When we went inside the base of the tower, I was surprised to find that it was hollow, with the cords from the generator coming down the side and a ladder and an elevator going up two other sides. Interestingly, the ladder and elevator were not bolted to the sides of the tower. Instead, strong magnets were used to hold them to the inside walls. This design put less strain on the walls, giving the tower more structural integrity.

After we were done getting a closer look at the wind turbine, we returned the helmets and the safety glasses to the main building, said our goodbyes and headed back onto the bus. As the bus rumbled back to UW-Madison, I thought about some of the less technical concepts that were discussed during the tour. For example, I learned that a wind farm must be closely integrated with the community in which it exists because the wind turbines are spread out in between houses and properties. A coal power plant, on the other hand, is contained on a single isolated plot of land that people can easily avoid as they go about their everyday lives. But because of the far-ranging, ubiquitous nature of wind farms as well as the fact that not all people see the value in them, wind farming is not a universally appreciated practice. Therefore, a wind farm has to work hard to keep its neighbors and inhabitants happy, which significantly affects the priorities of the wind farm's management. Seemingly inconsequential issues such as noise levels and aesthetics are given greater consideration because they are a matter of public relations. And on a wind farm, public relations are a pretty big deal.

> "...about 1.65 megawatts on a windy day."

So as I sat on the bus talking with the people who went on the tour with me, I considered what I was going to write for this article. I thought about the simple engineering of the wind farm. How it drew on a source of energy so basic to our earthly existence that cavemen understood how powerful it could be. How the structure and design of the tower seemed so basic from the outside, just another wheel spinning at the top of a stick in the mud. I thought about how even on a wind farm, a place all about science, math, and engineering, humanity and human interaction still played a decisive role in how the wind farm operated. And then the bus arrived. We were back at UW-Madison, and it was time for me to write. W/E

Written by: Connor Welch
Photography by: Simon Hensen
Design by: James Johnston

WHY ARE HUMANS UNIQUE?

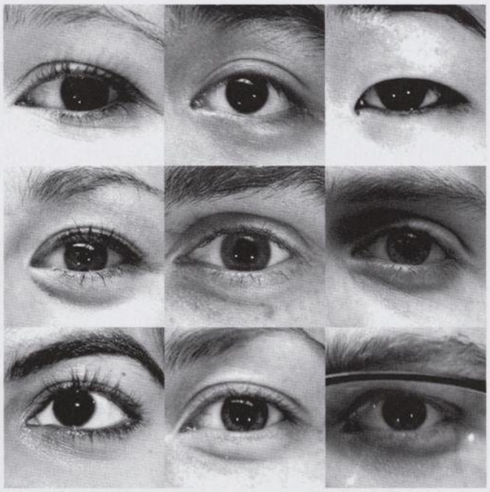
The challenge of characterizing stem cells may reveal the uniqueness of human identity at a fundamental level.

As one of the most popular topics in science fiction and movies, embryonic stem cell technology has drawn a lot of attention since being discovered. Both technical and social issues, however, have created challenges for scaling up the technology. Although frustrating, those challenges seem to reveal that stem cells are unique and refuse to be characterized and standardized like abiotic objects. Professor Lind H. Hogles, a medical anthropologist at UW-Madison who has worked closely with engineers on stem cell technology, recently published a paper that reflects on these challenges and brings us insight into the identity of stem cells.

As the starting point of life, embryonic stem cells have a tremendous ability to evolve into all different kinds of tissue. Embryonic stem cells' pluripotent features are widely used in the medical field as they can serve as an external aid to help failed tissue or organs in the human body to revitalize and regenerate. The applications of stem cells range from replacement therapy, which allows us to cure previously incurable diseases, all the way to organ culture transplants. We can implant stem cells into a patient's failed organ to stimulate regeneration or we can use stem cells to culture entire synthetic organs. As the clinical need for stem cells increases, it is becoming more important to find a way to increase production of stem cells and put them to work.

In order to industrialize stem cell technology to serve the general public, it is necessary to create a standardized way of identifying, characterizing, and controlling stem cells. Stem cells develop very quickly, and only those remaining in the early, undeveloped stage can actually be used. Efficiently identifying the developmental stages of stem cells is still an issue. Hogles explains that cells in the body mature quickly and the process of maturing occurs continuously and in irregular timeframes, so researchers cannot simply take a snapshot to collect the important information about each stage of development. "Biological entities are elusive and transient," Hogles says. "Stem cell technology is nothing like traditional engineering in that you won't necessarily get the expected product, even if you put in the right combination of reagents." There are currently several ways of defining stem cells for different stages, but none of them are perfect.

According to Hogles, one of the most important early stage markers of stem cells is Oct-Protein, a protein that is associated with regulating pluripotency. However, this marker is also associated with tumor-forming cells. Both cancer cells and stem cells possess generative and proliferative features, so it is often difficult to distinguish the difference between an early stage stem cell and a mutated cell that could become tumorous. Rather than looking at the intrinsic nature of the stem cell, the cell's development stage can be identified through functionality tests of growth potential. By ignoring the inside, stem cells are treated as a simple function that receives input and is expected to produce output. If the output does not meet the expectation with given input, then the cells will be identified as something other than stem cells.



Stem cells are as unique and varying as the hallmark of individuality: the human eye.

This method requires the stem cells to be put into living organisms, usually mice. The result of this test is only correlative instead of definitive because the conditions within a mouse are much different from a human, and stem cells are subject to environmental changes. As cells are extremely sensitive to cell signals or cues, there might be elements in a mouse's body that do not exist in a human body. Therefore, the test is not ideal and can only be used as a reference.

Alongside technical challenges, the varying sources of stem cells have also caused challenges between different regions. From Hogle's years of observations, she found an interesting phenomenon: the identical treatment of two stem cells might actually produce very different results. This is because the cells are extremely sensitive to environmental changes and stem cells coming from different sources have distinct genetic makeups. This phenomenon results in the formation of regional conventions deviating from the international common standard. "Just like every restaurant and chef has a different secret sauce or ingredient, different labs have their own way of making things work," Hogles says. Thus, it's hard to create a common standard that applies to the entire field. The fact that embryonic stem cells even from the same genetic sources may act differently demonstrates that stem cells grown in different environments are very different from each other.

> **"Just like every restaurant and chef has a different secret sauce or ingredient, different labs have their own way of making things work."**
> **- Lind Hogel**

Nearly everyone in this world holds the belief that every individual is unique. Even twins, who have identical genes, may end up very different. The challenges faced in stem cell technology may better corroborate this statement: every individual is unique because the cell that started everything is unique.

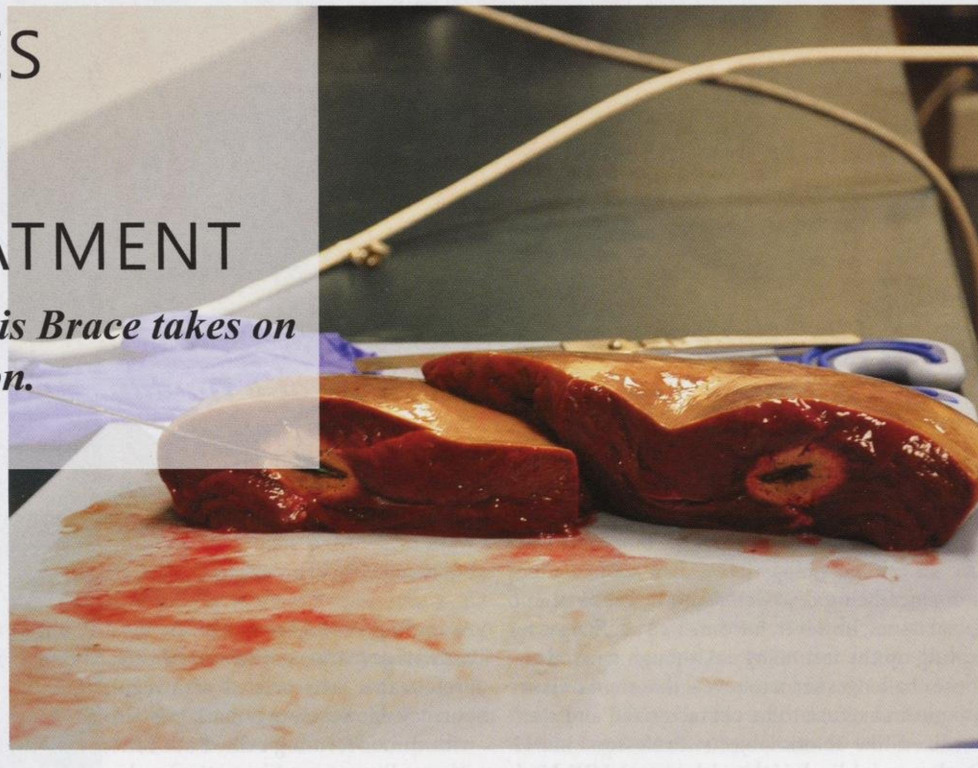
Written by: Ruite Guo

Photography by: Lili Haskins

Design by: Jonathan Evans

The Future is Bright for Cancer Treatment

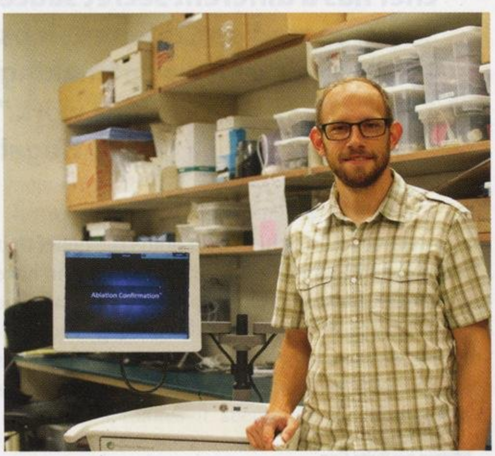
UW-Madison Professor Chris Brace takes on ablation with a secret weapon.



The liver cross section after heat ablation of inner tissue.

Cancer has long been at the forefront of medical scrutiny. It is the second leading cause of death, behind heart disease, and claims well over 8 million lives each year worldwide. Cancer treatments have evolved throughout the years and recently common treatments include invasive surgery, chemotherapy, and image-guided ablation. Ablation is becoming more and more popular in the medical world, as it isolates and treats the cancerous tumors while causing minimal collateral damage.

Ablation treatment was initiated in the 1990s, when cryogenic probes were used to freeze the tumor area and kill the cancerous cells. Ablation can also be performed by heating the isolated tumor areas, which kills the cancerous cells. Since this technique is newer to the market, it had some initial shortcomings such as the limited size of treatment, which was originally around three centimeters. With the help of determined scientists including Professor Chris Brace from the UW-Madison department of radiology and biomedical engineering, ablation has been developed into a more efficient and safe treatment with lessened collateral tissue damage. Brace's work with cancer deals specifically with image-guided ablation, which involves using MRI technology to allow surgeons to view the treatment live.



Professor Chris Brace with his NeuWave ablation machine.

Originally, Brace studied electrical engineering and physics at the undergraduate level and was interested in robotics and automation, but his exposure to the health care field inspired him to pursue a career in medical design and development. He studied MRI technologies while interning at GE Healthcare and was so fascinated that he went on to do many years of medical research in the same field. In 2003, Brace joined forces with a colleague to study microwave ablation, and focused his research on designing an antenna to supply the microwaves to the ablation area. Brace also experiments with antennae for cryogenic treatment, which is the freezing and removal of the cancerous cells from the surrounding tissue. These antennae went through various design stages, eventually evolving into sophisticated devices with the impressive level of accuracy they have today.

Brace's countless hours of research led him to establish a medical device startup company now known as NeuWave while still in graduate school. The company used simulation tools and optimization algorithms to refine concepts and to predict the morphology of an antenna before and after the treatment, some of which heat body tissue to over 150 degrees Celsius. With a combination of applied science and creativity, NeuWave was able to test their antenna prototypes with tissue models to predict temperatures and water distribution throughout an organ. Brace's work with antennae spanned over a decade, and NeuWave was eventually sold to Ethicon, which has used NeuWave's products to treat over 10,000 patients in need of image-guided ablation treatment. Brace's group continues their work every day to advance antennae so the procedures may continue to be more efficient.

While ablation is becoming more prominent in the world of cancer treatment, it is still in its infancy. Many researchers are working relentlessly to create an even less invasive treatment, called transarterial chemoembolization (TACE), which involves the delivery of isolated chemotherapy while using the visual aid of x-ray guided catheters. When combined with microwave ablation treatment, TACE could be a highly effective and minimally invasive cancer treatment. Many patients will receive the treatment only one time, which is sometimes sufficient to remove any and all residual cancer cells.

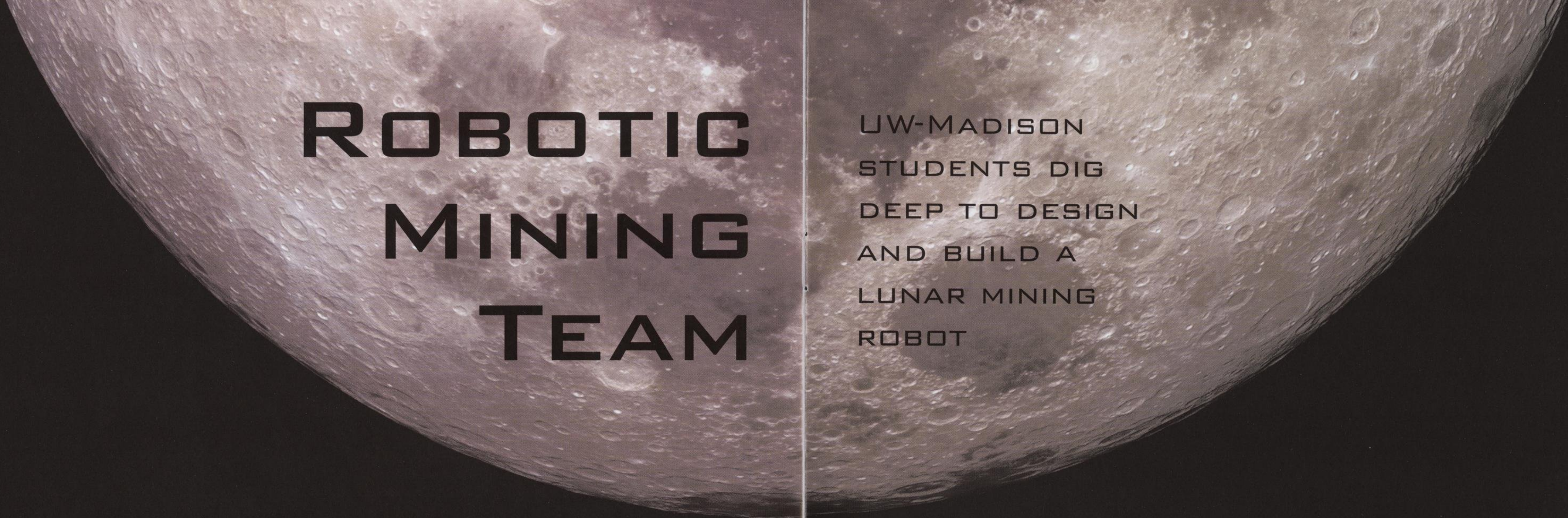
Although ablation can be used on most organs of the body, there are some areas the treatment has difficulty reaching. Areas such as the liver, thyroid, and brain are difficult or impossible to treat due to the high risk of affecting nearby cells and the inability to clot blood in those areas. Tumor size is also a large factor when assessing if ablation is the most effective way of treatment, and many larger, more developed tumors are more difficult to treat.

Despite these challenges, Brace and his affiliates are determined to push this technique to the forefront of cancer treatment. As this research progresses, Brace's passion to help those in need will drive him to greatly impact the medical field that has saved countless lives.

Written by: Chris Hanko

Photography by: Lauren Kuzminski

Design by: Patricia Stan



Robotic Mining Team

UW-Madison students dig deep to design and build a lunar mining robot

The quest for humans to return to the moon and explore other planets is met by many significant challenges. The advancement of privatized spaceflight can help to solve the problem of reaching these destinations, but this still leaves the overarching issue: How do people survive in a foreign environment with so few resources? The Badger Robotic Mining Team (BRMT) aims to answer part of this very question with its student-built lunar mining robot. Every May, college students from around the country display their unique robot designs in the NASA-funded Robotic Mining Competition (RMC) in Cape Canaveral, Florida. The RMC simulates the lunar mining environment where students' robotic projects tackle the resource acquisition problem. This upcoming year will be the second time UW-Madison students will compete in this competition, so they hope to make great strides to place this time around.

Tashi Atruksang, president of the BRMT and of UW-Madison's chapter of the American Institute of Aeronautics and Astronautics (AIAA), leads the way for fellow badger students not only to succeed in the competition but also to develop skills that will be crucial in their careers. Over the course of the fall semester, the mining team focuses on designing their robot. Students involved in this organization develop hands-on skills working in the student shop and computer skills using Computer Aided Design (CAD) software to design different aspects of the robot. Webmaster David Zeugner holds Solidworks seminars to teach new members how to use this CAD software, so students with no prior knowledge of CAD or robotics can join the team. Students on the team come from various backgrounds including engineering mechanics and astronautics, geological engineering, and computer science, and this diversity is what helps the team thrive. "To be able to see things from everyone's views and integrate that into your own ideas not only makes you a better engineer but also a better person to work with," explained Tashi.

The competition is broken down into five categories: On-Site Mining, Systems Engineering Paper, Outreach Project Report, Slide Presentation and Demonstration, and Social Media and Public Engagement. Each category is worth different point totals, so just having a robot that mines the most material will not necessarily win the competition. During the mining section of the competition, each robot is allotted two ten-minute trials on subsequent days to excavate the most material with their robot and dump it into an elevated bin. The terrain is one of the trickiest parts of the competition because there are craters or rocks that the robot must avoid before reaching the area where they can mine material.

The robot then needs to traverse back through these obstacles to dump the material in the bin. The material the robots excavate is called BP1, and it is the consistency of flour. Since it is so powdery, robots cannot get very much traction from it, so it is easy for a robot to get stuck somewhere inside of the enclosure. "The biggest key to success," Tashi stresses, "is organization and consistent dedication." Since a lot of work goes into this project, it is important that each CAD drawing or design is documented well and formatted neatly, so they can be put together in report for NASA.

To add further difficulty to the competition, more points are rewarded if the robot is fully autonomous, or requires little to no human steering or interaction while mining and/or depositing material. This aspect of the project proves difficult because the robot needs to recognize its surroundings and locate where it is with respect to the dumping bin at all times. Although autonomy is not required in the competition, it adds another level of rigor that will benefit the team's score in the end. "This is why this project is interesting," Tashi explains. "It's complicated and that's what makes it fun." In many engineering classes and in the workforce, tasks will not always be easy, and this competition does its best to simulate these types of rigorous problem-solving environments.

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> **-Tashi Atruksang**

Last year at the competition, many unique designs of robots were on display. For example, there were some robots with a bucket ladder that excavated material continuously and some robots with an excavator similar to a construction vehicle. However, UW-Madison's team last year decided to use a scraper method which simply scraped the BP1, and a body that could elevate to dump material into the bin. Although last year's competition did not go as well they had hoped, it still did benefit the students involved. "Last year was a really good learning experience not only for this project, but for me and my leadership skills, organizational skills and preparation for deadlines," Tashi says.

With a year of experience under their belts, members of the BRMT now know a better formula for success. This year, testing of the robot will be done early and often throughout the months leading up to the competition to make sure all systems are working flawlessly. Lucky individuals can even see testing firsthand in the sand volleyball courts near the Lakeshore dorms. Since sand is not a perfect comparison to BP1 or lunar or Martian soils, Tashi also plans on testing the robot in flour once the new robot is capable of driving.

The BRMT will be working diligently over the next six months to perfect their design for competition. Make sure to track the progress of this team over the next semesters and watch them dig deep in competition in May. After all, this design could one day be used to pave the way for interplanetary explorations to better access the resources of those planets.

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