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wisconsin engineer

MAY 2016 VOLUME 120, NUMBER 3

CELEBRATING 120 YEARS

2016 Photo Contest Winner:
Space Needle
Photographed by Connor Quagliana

Photo Contest Finalists p. 11

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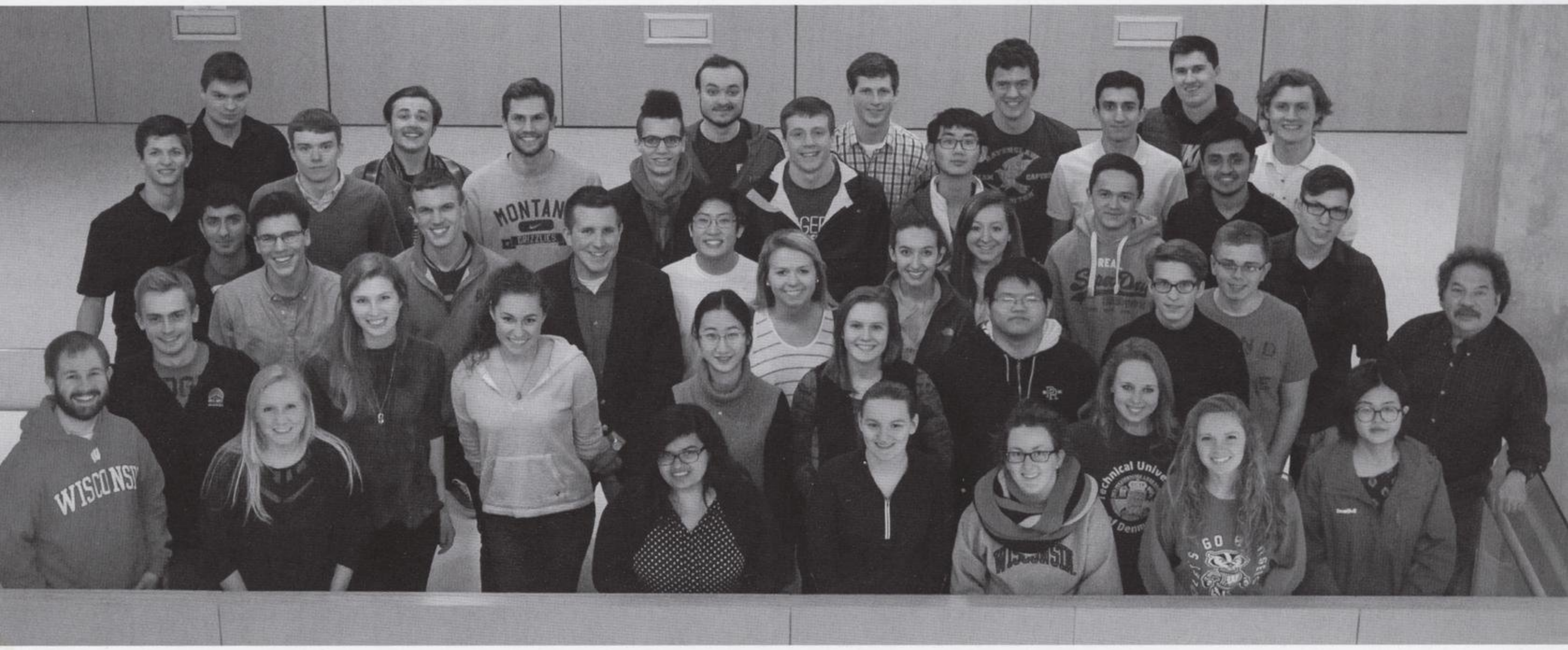

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General

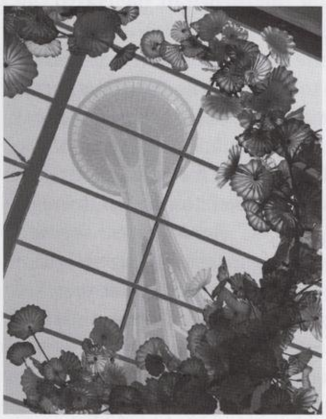

Photo Contest Overall Winner:
"Space Needle"
By Connor Quagliana

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Student Organization Spotlight

From the classroom, to the shop, to the race track, the Human-Powered Vehicle Club at UW-Madison prepares to show off their skills later this month.

Imagine a sleek, carbon fiber-encapsulated vehicle whizzing down a track with a top speed around 80 miles per hour. Rather than being powered by fuel, this aerodynamic vehicle is entirely human-powered and operated, its design allowing for maximum efficiency in converting the rider's muscle power into kinetic energy. This is the end product of a year of designing, fabricating, and testing with the Human-Powered Vehicle Club (HPVC). Each May, teams from around the country meet to show off their innovative bikes and trikes at the Human-Powered Vehicle Challenge hosted by the American Society of Mechanical Engineers, which will be in Athens, Ohio this year. There they are judged on a variety of categories, such as speed, handling, safety, sustainability, and creativity.

Leading HPVC at UW-Madison are President Karl Niendorf (junior) and Chief Engineer Luke Benish (senior), both majoring in mechanical engineering. The club was in the midst of its peak fabrication period earlier this semester. They kept busy in the Engineering Centers Building student shop, where the fairing (the outer casing of the vehicle) subteam was working on creating a mold for casting the carbon-fiber fairing shell. Ordinarily this would be done with a machinable foam, but the team decided to take the more environmentally friendly (and tedious!) route by gluing scores of cardboard slabs together instead.

Several of the members in the shop were freshmen or new to the organization altogether, as Niendorf explained, "One thing that makes our team unique is the way new members can get involved." Benish holds seminars for those who want training in certain skills, which means even those who have little or no prior experience can become active, contributing members. "I try to make a point of including all the team members in the design and teaching them how to use different CAD and analysis programs," Benish says. Everyone has the chance to work in the shop and obtain real machining know-how, which is instrumental when looking for internships or trying to stand out to potential employers. In fact, members will often be appointed to lead mini design projects so that components of the vehicle are created by different people before being integrated into the final product. "With a lot of teams, you have to be in [the club] for a year or two before you can really do much," Niendorf says. "Here we really encourage new members to start right away by giving them a design project." This is a valuable characteristic of the club that makes it such an asset to aspiring engineers.

"You're not just hearing about the theory in the classroom, you're applying it to the bike," Niendorf says.

The Human-Powered Vehicles Club at UW-Madison is completely run by students who come from all different disciplines. Naturally, the club attracts many mechanical engineers, but there are also biomedical engineers to deal with ergonomics, electrical engineers to wire the turn signals and brake lights, economics majors to handle sponsorship and funding, and essentially anyone who has a passion for bikes.

Being an engineering organization, the design process is virtually sacred. The group is broken up into four subgroups: fairing, frame, drive train, and innovation. The four teams come together at the weekly full team meetings to incorporate all their work and make a cohesive design. They are always looking for new ways to bring the team together and bond with events such as ice skating nights – this is a big part of building an efficient, high-performing team.

The club acts as a beneficial extracurricular supplement to the students' classes, particularly those that teach the design process. "You're not just hearing about the theory in the classroom, you're applying it to the bike," Niendorf says. Both Niendorf and Benish consider one class in particular, Intro to Engineering 160, to be particularly useful. This is a class that most freshman engineers take, and it includes a lab that allows students to create a product for a real client. "We follow almost the same skeleton as 160 throughout the design process," Benish says. Together they brainstorm, design, test, and redesign all aspects of the vehicle to improve each year. Often, after coming up with several ideas, the small design projects for new members will deal with fabrication of pieces that could take alternative forms in order to decide which is superior, such as concave versus convex wheel covers for the lowest coefficient of drag. Testing plays a huge role in determining whether the vehicle meets the specifications of the annual competition. When the vehicle can average speeds greater than 45 miles per hour, it becomes a necessity to achieve maximum safety for the operator. For a safety test, the team even brought their design to the Shell in order to utilize the Smith machine (equipment found in the weight room) to see how much weight it could bear with less than a cen-

The fairing sub team working on creating a mold for casting the carbon-fiber fairing shell.

timeter and a half of deflection. If these tests prove to be unsatisfactory, then some parts of the project may warrant a redesign.

The theme for this year's challenge is sustainability, so the group is focusing on efficiency and environmentally friendly materials. This boils down to simple choices such as using steel instead of aluminum and recycling old parts from previous years. The design is wrapped up in a comprehensive technical report, and it is then presented at the competition. Everyone in the club is given a voice in the design process, and all those who are active and contribute at least four hours of fabrication time in the shop each semester will be invited to the competition in Ohio. The team is nondiscriminatory, so the bike is prepared to adjust to people of different heights and weights. All members who want to ride the bike will have the opportunity, especially during the final testing stages before competing. This is a freshman-friendly organization, so anyone who likes hands-on experience and early leadership prospects is encouraged to check it out.

Good luck to our fellow Badgers in May. All are welcome to join the Human Powered Vehicles Club – just remember to wear a helmet!

For more information, visit http://hpvc.slc.engr.wisc.edu/new/

Written by: Edwin Neumann
Photography by: Martin Johnson
Design by: Toby Sun

Fact or Impulsive Assumption?

The Planet Nine Hypothesis

Get ready to change the way you think about our solar system

Curiosity and desire to learn - these are the human qualities that contribute so much to technological progress. This innate curiosity has once again revealed something spectacular. On January 20th, 2016, an article was published in The Astronomical Journal about the mysterious existence of another planet in our solar system, "Planet Nine." Although this theory is still in hypothetical stages, astronomers may be able to have physical evidence in the very near future. Get ready to change the way you think about our solar system.

The Planet Nine theory was first revealed by the ambiguity of certain elliptical orbits of objects in the far reaches of our solar system. A collection of asteroids, comets, and small ice bodies known as the Kuiper Belt has been observed to endure a distortion in orbits due to the gravitational pull of a large object, thought to be a planet beyond Neptune. Dr. Jim Lattis, director of the UW-Madison Space Place and faculty associate in the Astronomy department states, "After tracking their orbits with telescopes and cameras, a pattern emerges that all the orbits have an orientation that could not happen by chance." This means that there is something out there creating this disturbance, and now it is up to astronomers to find out what it is.

So, let's get into the possible physical characteristics of this so-called "Planet Nine." Theorists believe that Planet Nine originated in the center of our solar system and was then ejected to the far reaches of the Kuiper Belt, 10 times farther from the Sun than Neptune. "The Planet, if existent, would roughly have a mass similar to Uranus and Neptune, about 10 times that of Earth's," Dr. Lattis hypothesizes. Based on computer simulation, Planet Nine was also calculated to be about 600 astronomical units (5.6 billion miles) away from the center of our solar system. This distance means that Planet Nine would take anywhere from 100,000 to 200,000 years to make a full revolution around the Sun. Although no composition tests have been completed, the theoretical planet is presumed to contain Hydrogen and Helium and to be a gas giant, similar to the compositions of Uranus and Neptune.

Despite these calculations, we need to keep in mind that this planet has yet to be seen by anyone, or any telescope for that matter. So what happens if this theory is completely bogus and there is not actually a "Planet Nine"? Since we are seeing an early prediction based on modeling and simulation rather than physical evidence, we cannot say with certainty that this planet exists. The alternative could be that a very large brown dwarf, a sub-star object that is too small to sustain the hydrogen-1 fusion reactions that occur in the cores of conventional stars, passed through our solar system and changed the orbits in the Kuiper belt. This phenomenon would be very hard to detect given how dim brown dwarfs are; they emit almost no visible light and can only be identified using use infrared technology, which is very imprecise. However, the chances of Planet Nine existing are extremely high based on professional predictions.

At this point you're probably wondering, "What about the original 9th Planet, Pluto?" In 2005, Dr. Mike Brown, a planetary astronomer from Princeton University has identified another ob-

Could the ninth planet be out there, somewhere in the night sky?

"The Planet, if existent, would roughly have a mass similar to Uranus and Neptune, about 10 times that of Earth's,"
- Dr. Jim Lattis

Dr. Jim Lattis talking about the discovery and possible structure of the 9th Planet

ject that he believed to be a planet in the Kuiper belt, called Eris. Eris is roughly the size of Pluto and shares many physical characteristics. However, Eris was defined as a dwarf planet, and this began a series of discoveries of multiple other common dwarf planets in our solar system. These findings eventually discredited Pluto as an actual planet in our solar system. However, the entire discussion isn't really that consequential. "The word 'planet' is only a common word, not a scientific word; it's like questioning if Plymouth Rock is a boulder or a rock," Dr. Lattis says. Pluto should not be our main focus anymore, as Planet Nine is the main phenomenon that needs to be identified.

While astronomers can't agree on whether or not Planet Nine exists, they can agree that it should be easily spotted with large telescopes like the Subaru Telescope located in Hawaii. This telescope can be used to find more distant and dimmer objects in our solar system than most telescopes can't detect. A couple of months of scanning the sky in the region where the new planet is predicted to be just might provide direct observational evidence of its existence. Whatever happens next will surely keep the world curious, and we will be in the passenger seat to witness something amazing. WE

Written by: Chris Hanko

Photography by: Eowyn Liu

Design by: Jonathan Evans

?

STAR WARS:

THE FORCE AWAKENS

Star Wars: The Force Awakens introduced us to a new droid BB-8 that might not be science fiction for long.

In 1977, the world fell in love with a robot for the first time. That year, the first Star Wars movie smashed box office records and introduced a host of characters that became pop culture icons, including the lovable droid, R2-D2. With the creation of R2-D2 and his companion, C-3P0, Star Wars creator George Lucas pioneered the concept that robots could have likeable personalities and be faithful companions to humans. Arriving the same year Apple moved out of a garage in Silicon Valley, these droids seemed as wholly futuristic as lightsabers and warp speed spaceships. Fast-forward to December 2015, when the Star Wars franchise introduced a new loveable robot named BB-8. This time the reaction was different. The question moviegoers asked changed from "Could this be possible someday?" to "Where can I buy one?"

BB-8, named for its resemblance to both two B's and an 8, became not only the face of Star Wars: The Force Awakens, but also the face of the toy industry in 2015. Sphero's smartphone controlled BB-8 robot was one of the best selling and most talked-about toys in 2015. Sphero is a robotic toy company that specializes in spherical robots, specifically their namesake Sphero robot. They were invited to Disney's technology accelerator for startups where they were approached by Disney's CEO Bob Iger about making a toy based on the then-secret BB-8. The Sphero BB-8 is controlled by an app in the user's smartphone and can either be driven or allowed to explore its surroundings freely, learning and remembering its environment as it bumps into things. The main body is controlled by a self balancing, gyro-driven ball largely based on the original Sphero toy. The head is attached by two keyed magnets, making it possible to have a freely spinning body underneath a stationary head that allows the robot to always know which direction is forward.

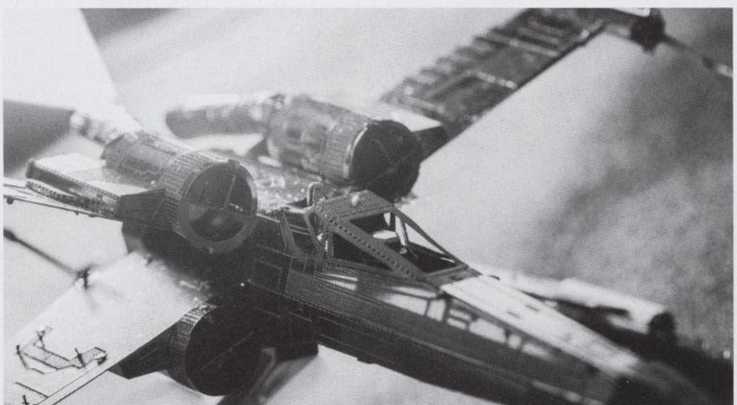
While the BB-8 toy is a fun version of the droid that any Star Wars fan can have as a companion, the closest thing to a working, life-sized BB-8 was developed by the Star Wars team for the movie's promotional events. Due to both time constraints and the necessity of having different robots for different types of shots, Disney's "creature shop" team didn't make a fully functional BB-8 for the filming of the movie. Instead, they made many different partially functional BB-8 puppets in order to stick with director J.J. Abram's desire to depict BB-8 without computer-generated imagery. However, while the team was churning out various BB-8 props for filming, they were also working on their dream of creating a fully-functional remote-controlled droid. At the Star Wars Celebration in April 2015, the life-sized BB-8 surprised everyone by rolling out onto the stage. The robot playfully rolled around R2-D2 and displayed its cute and coy personality by the way that it moved and the sounds that it made. The crowd went wild. Unlike the Sphero team, the team from the Star Wars creature shop didn't reveal how they made BB-8 work. They did, however, reveal that the mechanical technology required to create and operate a full sized BB-8 is already here.

Every BB-8 made so far has been controlled remotely by a human. The only remaining obstacle to creating a real BB-8 droid is the lack of computing technology necessary for making completely autonomous, self-aware robots with personalities. There are many promising signs that indicate this won't be an obstacle for long. Research into advanced areas of robotics is only increasing as engineers continue to develop robots that accomplish diverse tasks, from driving cars to communicating with customers in malls.

The only remaining obstacle to creating a real BB-8 droid is the lack of computing technology necessary for making completely autonomous, self-aware robots with personalities.

In 2015, Google was granted a patent for their method of creating adaptive robot personalities. Their patent involves having robots that can actively attempt to read human emotions and respond accordingly. Another huge step forward also occurred in 2015 when researchers at New York's Rensselaer Polytechnic Institute developed a robot that was able to pass a self-awareness test previously thought to only be passable by a human. In the test, the robot was able to recognize its own voice and identify itself as being separate from the other robots in the test. This and other technology could soon be combined in the creation of a self-aware robot with a distinct personality, or perhaps the creation of a loveable droid.

When the original trailer for Star Wars: The Force Awakens was revealed in late 2014 featuring a rolling droid, many people questioned whether or not it was possible to make a machine move in such a way. Disney and Sphero both answered by creating rolling, beeping, heading-spinning, remote-controlled versions of the droid. But, having that question answered only raised a far more important one; with Disney slated to release at least 5 more Star Wars movies, will we be celebrating a future release with a real, autonomous BB-8? As the line between science fiction and reality continues to blur, that galaxy far, far away seems quite a bit closer. WE



Though building a working X-Wing (above) may be a far-fetched idea, the technology to bring BB-8 to life exists right now.

Written by: Eric Fleming

Photography by: Seth Reuter

Design by: Tim Campbell

From Ideas to Apps

Two UW students offer firsthand insight into the process of creating an app.

What do Snapchat, Eatstreet, and Zuntik all have in common? They all are apps that began as college startups, each one the dream of students who saw an opportunity to provide something new and exciting – and didn't waste any time seizing their chance. The frantic, ever-changing culture of the startup world has permeated much further than one might expect. Companies such as Perblue, a social gaming company, and Eatstreet, an online food ordering platform, come to mind as two of Madison's most prevalent examples. It can seem a bit intimidating to contemplate jumping into this maelstrom of all-nighters, funding searches, and the grind of trying to gain publicity, but the two students behind a new Madison-based event sharing app have experienced it all firsthand. Zuntik co-founders and UW-Madison students Liam King and Jake Schieber were willing to share a bit of advice to those who think they might have come up with the next big thing.

The first major step to developing an app is to have a goal in mind, and a list of things that you would like to see in the final product. According to King, professors can be of great help in getting an idea off the ground. They also can assist with an important step of the development process called "pivoting," which means modifying the goals or features of the app to either avoid an issue or to focus more successfully on a certain user base. For example, Zuntik began as an idea for a more specific app that would promote events for student organizations and other groups within the university. However, the goal changed as King and Schieber realized that student orgs are a difficult group to market to, given the high rate of leadership turnover and the private nature of many of their events. This experience helped them to identify that their product would be better suited to public events such as concerts, festivals, etc., that are advertised to the general population. Pivoting like this occurs many times in almost every startup as they refine their product. "Although it's your app, the people ultimately get to decide how it's being used," says Schieber.

After the concept has been narrowed down and a general outline of the product's functionality decided upon, the next step is to develop the actual software and coding. This can be a major source of confusion and anxiety, and often leads to the temptation of paying a third party to develop the app. The Zuntik founders discovered that this approach typically creates more problems than it solves because the cost of implementation can begin to add up and often doesn't produce a high quality product. Instead, Schieber recommends developing the app in-house, which both saves money and allows for much more flexibility. He had never developed web code or mobile apps before beginning work on the precursor to Zuntik but decided to teach himself, and now personally writes all the code. "If you have an idea, it's really about working really, really hard to do it yourself," Schieber says. "If you need to find somebody to join you so you can do your thing and they can do their thing, find the other half." If you don't have experience with coding, there are several organizations in Madison such as MadVentures that connect students with similar ideas and different skill sets. For example, King is a Marketing and Finance double major, while Schieber is a Computer Engineering and Computer Science double major, so they are able to split up responsibilities accordingly.

The two cofounders of Zuntik - Jacob Schieber (left) and Liam King (right). Jacob is the CEO and Liam is the CMO.

After an app has been developed, the best way to bring it to the public is through Apple's App Store and Android's Google Play, which both have their own unique way of receiving submissions for new apps. This process can be a bit tedious but there are many tutorials online about how to go about submitting an app to these online stores. One thing that Zuntik uses for its code for the app store is an Ionic Framework. This is a software tool that makes it simple to design an app and later upload updates to the app store quickly as the app is developed and refined.

Following public release of an app, it is time for repeated refinements based on early user feedback to ensure that nothing is confusing the customers. For example, Schieber and King encountered a peculiar issue with their "communities" feature. "No one knew that they had to join at all. We saw this trend of not many people joining certain communities, even though right when you open the app you get a suggestion to join." King explains. "The suggestion was just too small for them to realize 'Oh, that's an action that's clickable.' And then we changed it and up went the joins." Problems like this are sure to come up in any new product, and the key is again to be open to pivoting to meet user demands while keeping in mind a consistent end goal for the app.

Now that Zuntik has been available to the public for a few months, King and Schieber are making plans to introduce their app to other campuses. They are just one example of the many apps and startups that have come out of Madison in general, and UW-Madison in particular. Many opportunities and resources are available here for anyone who is willing to take advantage of them. The unique world of app development has a culture that attracts a wide variety of people and ideas. "It will always be dynamic and changing, which keeps things fun and interesting," says King. "But at the same time everything will break. There will be something that you completely forgot or didn't think of, and that's okay." It's certainly a challenging undertaking, but one with a plethora of exciting possible outcomes. "You're constantly learning and trying to adapt to the situation and that's just the fun of it," King says. "It's one of the most rewarding experiences you'll ever be able to have."

zuntik

Written by: Ben Zastrow
Photography by: Therese Besser
Design by: Tanae Swenson

The Human Exoskeleton

3D printing is making custom-made assistive technology more accessible.

According to the United States Census Bureau, nearly 20 percent of United States citizens have some form of physical disability. With such a large amount of people with conditions that may hinder their ability to participate in daily tasks, there is a great demand for technology to help make their lives easier. The technical term for this technology is called assistive technology: a piece of equipment that improves or maintains the functional capacity of a person with disabilities. However, as 3D printing becomes more mainstream and cost efficient, the assistive technology market has opened up for everyone.

Through UW-Madison senior capstone design projects, students are connected to clients who present them with various engineering challenges. A UW-Madison mechanical engineering design team of Aevyrie Roessler, Stephen Wisniewski, Joseph Bradel, Shengyu Liu, and William Mann under faculty advisor Heidi-Lynn Ploeg, is working on a piece of assistive technology for a client with Arthrogryposis Multiplex Congenita (AMC). AMC is a rare condition in which a joint is formed permanently in a bent or straight position, affecting movement of the joint. The symptoms of AMC are present at birth and vary in severity; in most cases, it movement becomes very difficult, as muscles are underdeveloped and joints are swollen shut. Such is the case for the team's client, a seven-year-old boy whose upper limbs are affected by the disease. Because the client is in school, his father sought help from UW-Madison to ease his son's daily tasks like lifting and moving his arms.

"Our hope is that this device can be used as a therapeutic device too, so as he uses it he can get a bit stronger and gain dexterity."- Aevyrie Roessler

Similar to others with AMC, the team's client had already done some therapy to help his mobility, which consisted of using a metallic exoskeleton that would open the arms to stretch the limbs and loosen the joints. "Our client has gained flexibility, but he still lacks strength in his arms, so our solution was to use bands to suspend his arms in the air so that he could pull his arms down to do daily tasks," explains communication leader and team member, Stephen Wisniewski. "Even though he has very little bicep muscle, in suspending the arms and working on the triceps and back muscles, his biceps could eventually function normally."

"We talked to the client about the exoskeleton that he used when he was four," says team member, Joseph Bradel, "and we talked on how we could improve the design and make it smaller and more comfortable to wear but still functional." The solution the team came up with is a new exoskeleton design that uses

Aveyrie comparing printed out unit to their model.

The exoskeleton team members: Shengyu Liu, Stephen Wisniewski, Aevyrie Roessler, WIll Mann, and Joseph Bradel.

bands and 3D-printed pins to make an affordable and lightweight exoskeleton that will allow the client to move his arms downwards to help his mobility. The prototype that the team had originally made was a vest-like creation that had no bulk, but it lacked the support to render it totally functional. "He's going to go to school with it, and we want him to be able to put on a sweater and not make it look like he's wearing some robotic scaffolding."

Another unique aspect of their design is that it will "grow" with the client, that is, with the help of 3D printed components. "In order to make our design 'grow' with the client, we want to make it as easy as possible for his dad to remake parts if they break or need to be scaled up," says team leader Aevyrie Roessler. "So we will give the CAD designs to the father so he'll be able to just go to a place with a 3D printer to print out new parts." According to the father of the client, very little equipment is on the market for people with AMC, since the disease is both rare and affects people differently on a case-to-case basis. His father had found the most reliable source for equipment was through the community he found at AMC conventions, where other people would spread the word about available devices and where to find them. "The advantage of our design is that you cut out going to the doctor and having them give you whatever expensive equipment they have for this condition, or paying another design team to create a whole new exoskeleton each time he grows out of it," says Roessler. "[Our client's] dad can just print out the parts for many years to come." Currently, the upfront cost of materials for the team's design is just $100. According to the team, it's not exactly certain how much it would cost to scale up the design for years to come, though with the growth in the 3D modeling business, the cost of printing parts will decrease as time goes on.

Unfortunately, there is no cure for AMC, and without proper development of muscles and tendons, people living with this condition would not be able to move easily without an assistive device like the exoskeleton this team is working on. "Essentially, by strengthening the pushing-down motion, we could strengthen the pulling up motion too, and give the client more functionality in his arms," says Roessler. "Our hope is that this device can be used as a therapeutic device too, so as he uses it he can get a bit stronger and gain dexterity."

With the help of 3D printing and clever design, this client can benefit from the team's product for years to come. Innovations like these will continue to make life a bit easier and not so much of a financial burden for people in need of assistive therapy devices. WE

Written by: Anastasia Montgomery
Photography by: Catie Qi
Design by: Jason Wan

Landscape

Rainier | Connor Quagliana

Category Winner

Mount Rainier on a Hazy Afternoon | Alex Dawson-Eli

Runner Up

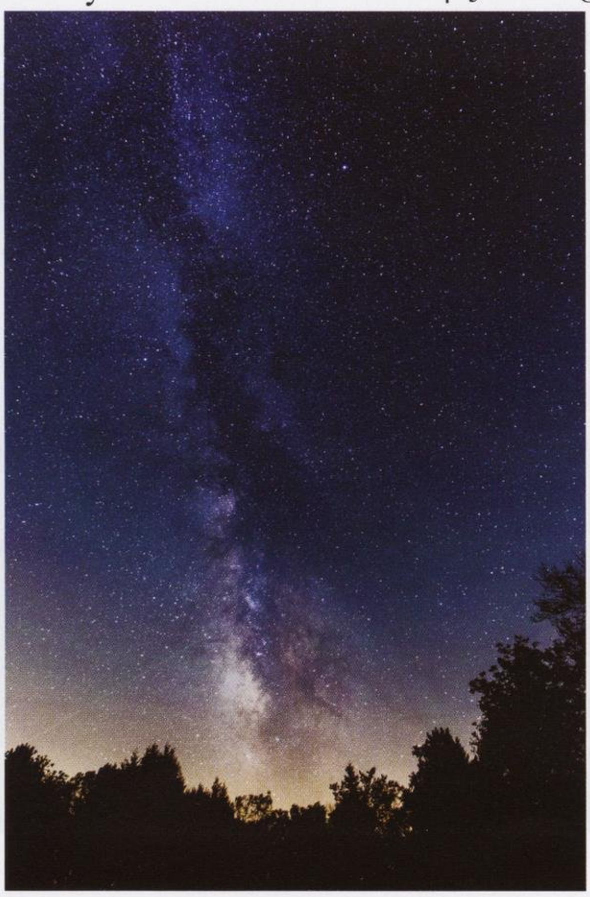
Miscellaneous

Star Trails Over Madison | Jerry Miao

Category Winner

Milky Way Near Madison | Jianheng Li

Runner Up



The Wisconsin Engineer's 8th Annual Photo Contest

The Wisconsin Engineer's 8th Annual Photo Contest

Portrait

Alone | Erik Kernozek

Category Winner

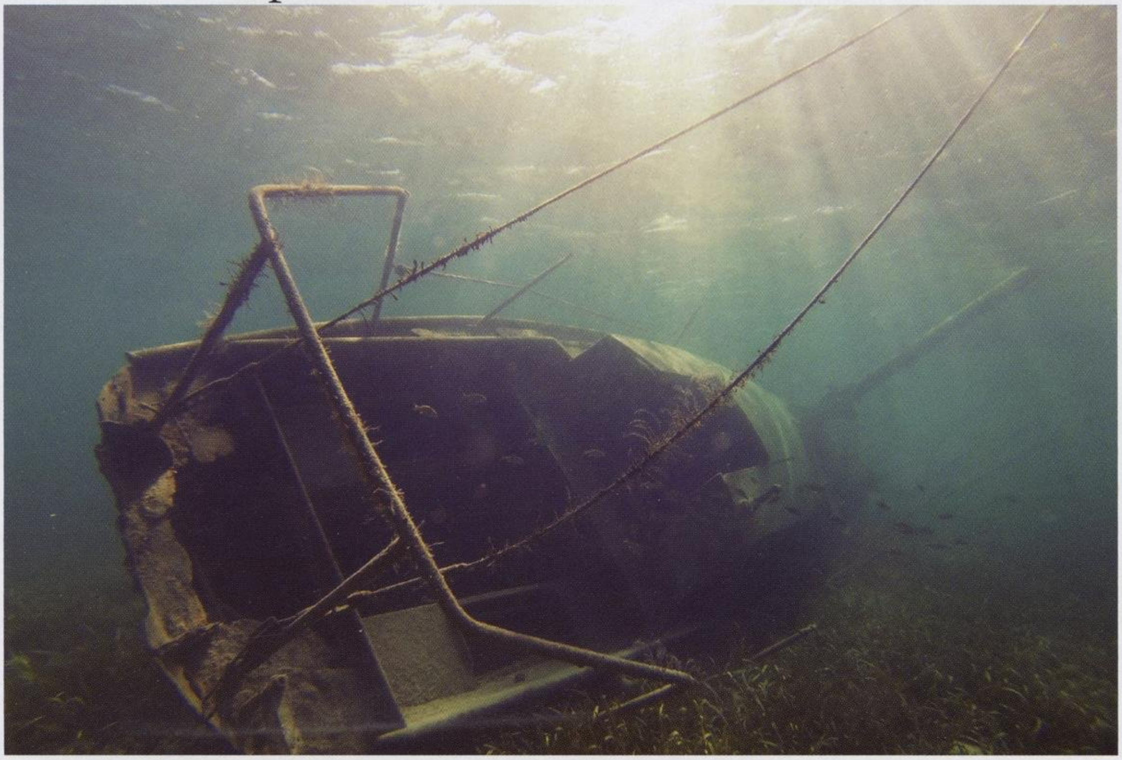
Tiny Ball of Fur at Indiana Dune State Park | Pranav Karanjkar

Runner Up

Still Life

Sunken Ship | Eric Shirtzinger

Category Winner



Beach Bums| Emilie Wille

Runner Up

The Wisconsin Engineer's

8th Annual Photo Contest

Fitness Tracking *Redefined*

What the chemicals in your sweat could be telling you with the right technology

Over the past few decades, people have become increasingly interested in tracking physical activity. Whether it is for health reasons, or merely to look and feel good, people have been seeking a more accurate way to track their physiological progress than a measly pedometer. They want to learn how to improve their day-to-day activities and eating habits, and to know more about their health. It was only in the past decade that fitness tracking devices made an enormous leap in capability and popularity, becoming a trendy commodity around the world.

One of the first major technological devices accessible to the general public was the Fitbit Tracker, released in 2008. The most recent iteration of this device allows you to not only count your steps, but also keep track of distance, time, and the amount of calories burned, all by simply attaching the device to clothing or placing it in your pocket.

As tracking devices developed, companies started looking for new designs. The Jawbone UP, released in 2011, was one of the first to implement a device the user could wear on their wrist. This new device could keep track of activity intensity, detect your mood, and determine sleep time and quality. This allowed users to better examine their physical activity and helped enhance sleep schedules, which could lead to improved moods and overall better health.

These devices have continued to evolve, doing more to help the user track their fitness. Announced in 2015, the Jawbone UP4, has even more abilities than thought possible in a wristband. With the app synced to a smart phone or device, one can log food, track their resting and passive heart rate, and even connect the device to an American Express credit card. On top of all of that, the program has a "Smart Coach" that interprets all of the data the user collects and gives them tips to improve their health and set personal goals.

With all of these capabilities at your fingertips, one would think there isn't much else to improve. But, what if there was a way to non-invasively read the user's bodily chemicals as to gain access to an abundance of physiological information? This is a question that Dr. Ali Javey, a professor of Electrical Engineering and Computer Science at the University of California-Berkeley, set out to answer.

Fitbit (Fitbit Flex pictured) is one of many activity trackers that is gaining rapid popularity with people from young children to

Javey and his postdoctoral fellows, Wei Gao and Sam Emaminejad, are affiliated with the Berkeley Sensor and Actuator Center as well as the Materials Sciences Division at Lawrence Berkeley National Laboratory.

Javey and his team have developed a prototype fitness tracker that can be worn as a wristband or headband and analyzes the chemical makeup of sweat. There are two components to the design. The first is a flexible circuit board, containing 11 computer chips, which can be condensed into one chip when ready for production. This element reads and sends the data received from the second portion of the device: a flexible plastic piece containing sensors that gather information from the sweat. These sensors target four analytes: sodium, potassium, glucose, and lactate – three more chemicals than any other sweat-based biosensors.

By continuously monitoring these chemicals, users will be able to tap into a whole new array of physiological information. Sodium controls blood pressure and blood volume, while potassium has various bodily functions such as building proteins, breaking down carbohydrates, and muscle building. Monitoring these chemicals will grant access to dehydration levels. Glucose and lactate, which take part in the body's energy levels, can give information on muscle fatigue. With this kind of information being read from a device on their wrist or perhaps a headband, athletes would have a revolutionary way to train and keep constant track of their health.

While helping athletes train more efficiently is a great development, this innovative device has the potential to do much more. Its ability to monitor sweat could allow us to assess medical conditions, discern drug abuse (prescription or otherwise), and possibly even detect molecules linked to depression. Emaminejad said in an interview with a Berkeley news reporter that, "The number of biochemicals we target can also be ramped up so we can measure a lot of things at once. That makes large-scale clinical studies possible, which will help us better understand athletic performance and physiological responses to exercise." This could potentially lead to the reading of hormones, diseases, and numerous other illnesses.

With such great potential, this newfangled device could have massive contributions not only to the world of athletes and fitness tracking, but also to medical analysis and applications. Incorporated with the already expansive capabilities of fitness trackers like the Jawbone UP4, this product would change the definition of athletic training and personal health entirely. WE

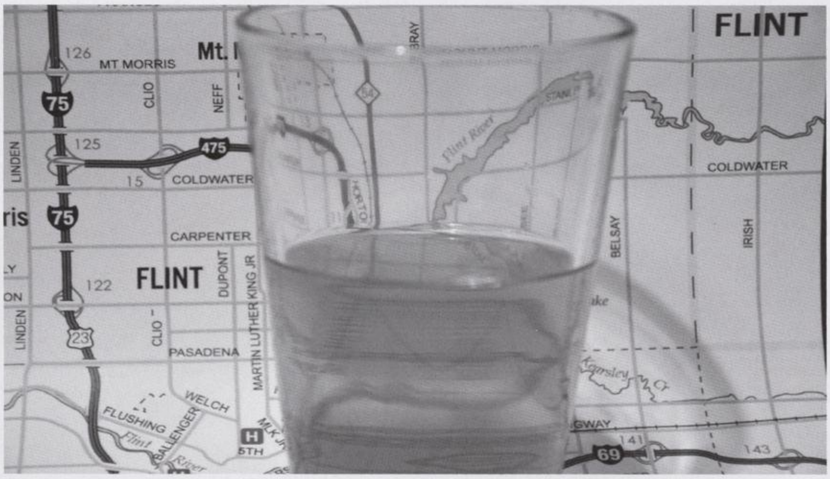
Written by: Matt Stout

Photography by: Brandon Moe

Design by: Suzanne Kukec

$\mathrm{H_2}$Ohh No!

With the recent events in Flint making national headlines, water quality in other cities across America has become a growing concern.



The average American uses around 157 gallons of water per day. This statistic accounts for all indoor residential, commercial, industrial, and institutional water one person is responsible for in one day. Professor Ned Paschke, a civil engineer and Program Director in the UW-Madison department of engineering professional development (EPD) generated this number as part of one of the many classes he teaches through EPD. Clean water is a vital part of life, so large issues arise when a city like Flint, Michigan has a crisis in which the city water is completely contaminated. Fortunately, when a problem like this is recognized and properly managed it doesn't have to be as big a problem.

Flint, Michigan once obtained its water from Lake Huron via the City of Detroit. Feeling this an unnecessary cost, Flint decided to switch their water source to the Flint River, known for its uncleanliness. The switch was intended to be temporary while a new pipe was built from Lake Huron to Flint. But soon after using the Flint River water, the residents noted the change in look, smell and taste of their water. Flint River water is highly corrosive and it was found that iron was causing the water to change color. The water, which was not properly treated with an anti-corrosive agent, was causing iron-made water mains, to erode, in turn resulting in brown, iron-filled water. While the visible change wasn't a desirable trait in itself, there was something far worse occurring that residents could not see. Half of the pipes in Flint, more specifically, pipes on private property that connect buildings and homes to water lines, called lateral lines, were made of lead. Since the water was eroding the pipes, the lead was leaching from the pipes into the water. It was found in August that the water contained highly elevated levels of lead. Lead poisoning, which is irreversible and terribly damaging to human health, became a concern for the residents. An anti-corrosive agent would have solved 90 percent of Flint's problem if it had been used originally.

While the story in Flint is a unique case, many cities across America still use lead pipes as their lateral lines into their home. The city of Madison was innovative in how they handled the lead situation. Madison eliminated the lead risk by replacing all lateral lines. While there are cheaper ways to meet the federal standard of lead in the water, none are as effective. The total project took 11 years and cost the city $15.5 million.

Water quality is a unique issue for every city across America. Some cities, like Madison, get their water from ground water sources, via a well system. Since this water is not exposed to as many contaminants, it requires less water treatment and cleaning. For example, Madison only treats their water with chlorine, a disinfectant, and fluoride, which improves dental health. Other cities get their water from rivers and lakes. Since river and lake water is more exposed to air and human contaminants, it may require more treatment procedures. Water treatment plants are maintained and regulated by the Environmental Protection Agency (EPA). Several acts have been passed throughout the course of history to help keep water regulations up to health standards. For example, the water that leaves treatment plants must be tested and confirmed as safe to consume. The problem with a lot of cities, however, is once the water leaves the treatment plant it is exposed to the deteriorating pipes.

While the water may be deemed safe to drink as it exits the treatment plant, various elements of aging pipes may cause it to be unsafe by the time it gets to a faucet. According to Paschke, "A greater amount of assets a water system uses is needed for the pipes." With the rise of suburban living in the middle of the 20th century, a lot of a city's water utility budget was used to build miles of pipes out to new residential communities. "Now, some 50 years later, for the first time, a significant part of what a water utility owns has become old because of this big growth of the 20th century." As a result, greater parts of a water utility budget need to go into repairing, replacing and upgrading a city's piping. "In concept, pipes are not as sophisticated as treatment plants. In cost, it's actually greater than the treatment plant," Professor Paschke claims.

The recent events in Flint have sparked cities across America to look into their water utility systems to see if there is potential for a similar event to happen to them. Advances in a city's water infrastructure, while accounting for only a small portion of the entire water system, remain vital to keeping the water safe. Not many Americans realize exactly how much water they use in a day, but if they did, this topic may become of greater concern. WE

Written by: Katherine Underwood
Photography by: Andrew Uehling
Design by: James Johnston

PARIS Climate Change Conference 2015

With the viability of the planet at stake, the 2015 Paris Agreement aims to combat climate change before it's too late.

Written By: Stephen Schwartz

Design By: Patricia Stan

More than 70 percent of Americans now believe climate change is real and caused by human activity; however, this wasn't always the case. While the first discussions of human-induced climate change date back to the turn of the 20th century, it wasn't until the 1970s when modern scientists began outlining the potential consequences of failing to address this mounting global problem. Since then, public support for counteracting climate change has steadily increased due to the growing and now insurmountable amount of evidence which supports its existence. With the future viability of the planet at stake, ambitious international efforts to stall and eventually reverse the effects of climate change have recently gained substantial momentum.

1995 marked the beginning of the international discussion when the United Nations Framework Convention on Climate Change (UNFCCC) held its first Conference of Parties (COP) in Berlin. Two years later, the Kyoto Protocol, which sought to set baseline emissions for participating countries, was adopted in Japan. A COP has been held every year since its inception, and in 2015, negotiations between 195 countries around the world resulted in the landmark Paris Agreement.

The major goal outlined in this agreement is to keep the average global temperature from rising more than 1.5ºC, with 2ºC being the absolute limit. As Dr. Ankur Desai, Associative Professor of Atmospheric and Oceanic Sciences and Faculty Associate at the Nelson Institute Center for Climatic Research, explains, "It sounds like a small number, 2ºC, but if you think about it, the difference between the last ice age and the present is only about 5ºC, and so you're talking about almost half an ice age unit." Raising the global temperature above this limit, Desai continues, would amplify the consequences that are already beginning to take effect as a result of climate change and lead to a severe decrease in quality of life, particularly for those living in developing countries.

"It sounds like a small number, 2ºC, but if you think about it, the difference between the last ice age and the present is only about 5ºC, and so you're talking about almost half an ice age unit."
– Professor Ankur Desai

While there are many adverse effects attributed to climate change, perhaps none are direr than those pertaining to food security and agriculture. With increasing temperatures, virtually all land areas used to grow crops will experience a decrease in productivity. "[This] is a big deal given that population continues to increase and that is fundamentally linked to our ability to feed the world," Desai says. Other critical repercussions include rising sea levels which directly impact low-lying coastal areas and island nations, disappearing ecosystems and biodiversity and the intensity of extreme events such as flooding, heat waves and drought. Take hurricane Sandy for instance: "The slightly higher sea levels made [its] impact a lot more devastating than it would have been otherwise," says Desai. With a majority of the world's political leaders now listening to the scientific community and recognizing the manmade nature of these disastrous effects, the Paris Agreement provides hope that the sanctity of the planet can be preserved.

When Laurent Fabius, President of COP21, declared that the Paris climate agreement was adopted on December 12th, 2015, the world collectively rejoiced. This marked the first time in over 20 years that the UN has achieved a universal agreement which aimed to keep global warming under control through reducing emissions and investing in greenhouse gas sinks. Even more importantly, it had succeeded in getting every major country, including the two largest emitters (the United States and China, something the Kyoto Protocol lacked), involved. "The Paris agreement is much looser and the idea is that it gets everyone onboard," says Desai, comparing this agreement to the Kyoto Protocol which established more strict regulations and placed the entire burden on developed countries. "The nice thing is there's flexibility," Desai says, referring to the fact that individual countries get to set their own emission targets under the Paris Agreement, "the negative thing is that it requires a lot of goodwill on behalf of the individual countries." This is because it still relies on developed nations to provide significant financial support to developing countries, but it also requires all parties to continuously reduce their target emissions over time. This is critical as climate change experts currently estimate that based on the 186 action plans submitted by participating countries, the globe would still be on track for an average increase of 2.7 to 3°C, well above the 2°C limit.

While there's clearly more work to be done, the Paris Agreement represents a large step forward in the right direction. The collective effort of so many different countries coming together to tackle this issue is unprecedented and represents a new era of international cooperation. With the ratification process already underway, it's only a matter of time before the Agreement goes into effect and it will be exciting to see how the world reacts as it transitions away from fossil fuels towards a cleaner, greener future.

Artificial, Yet Natural:

Robotics and AI

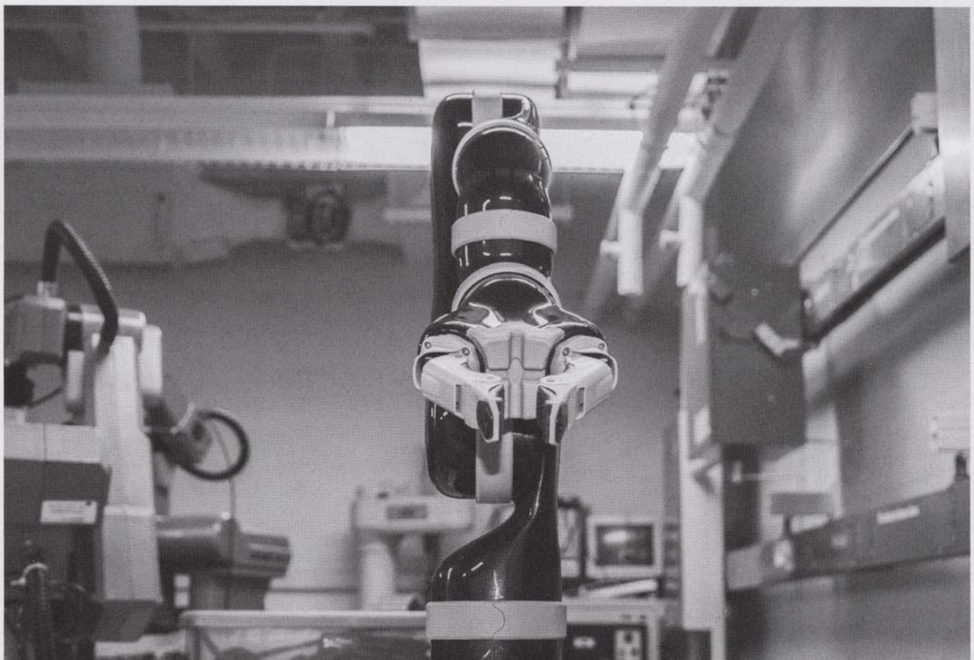
Bringing reality closer to science fiction proposes a future in which humans are no longer alone at the top of civilization.

Take abrief moment and picture the world prior to the Industrial Revolution. Few people yearn for times without our modern amenities, our technology. We safely conclude that the world ultimately benefits from the development of innovative tools, especially electronic tools. However, this exact moment in history holds the most rapid development humanity has ever experienced. The technological torrent of our time drowns the important conversations and observations needed as we enter an age where humanity is augmented with robotics and artificial intelligence (AI).

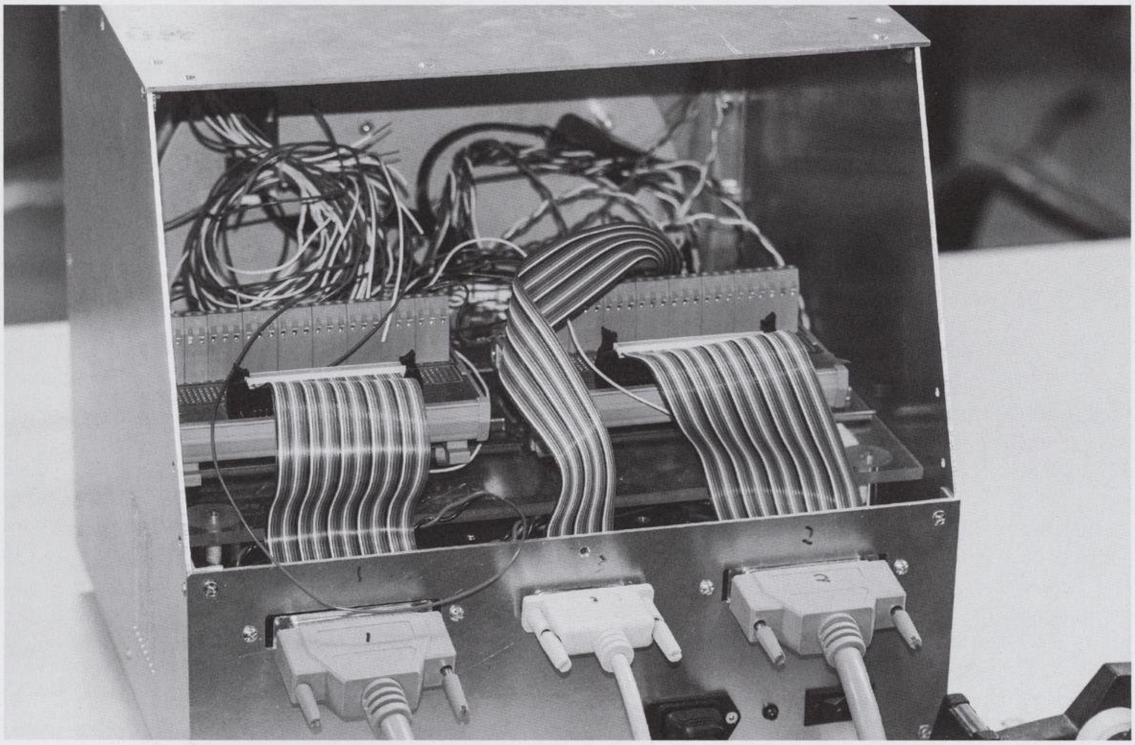
To begin, what is robotics? "[It] is an extension of the Industrial Revolution," says Michael Zinn, a Professor of Mechanical Engineering here at the University of Wisconsin-Madison. Professor Zinn researches minimally-invasive medical robotics, discovering superior ways to treat patients through applications of robotic systems. It is natural for humans to make a task easier through the development of tools. A robot is just a tool to accomplish societal goals and make the human existence better. It is controlled through of a series of controlled electrical impulses which translate mechanical systems with little-to-no external intervention. However, many robots do not possess intelligence; the exact sequence of electrical impulses are predetermined by a human trained to create the desired motion. Based on this information, we can conclude, say, the Bellagio fountain in Las Vegas is a robotic system but, like most other robotic systems, does not possess any sort of intelligence.

What happens when robots are able to make decisions, though? When an electromechanical system possesses the ability to perceive its environment and respond accordingly, one can say the system possesses a certain level of "intelligence." However, we must ask if the system is following a predetermined list of commands to escape the situation rather than dynamically solving the problem. The average assembly-line robotic system is programmed to silently perform a single task as long as its motors move. We see a different scenario, however, when a robotic system can be taught a task through human-to-robot training sessions. A well-known robot of this sort is known as Baxter, a robot with a face and two arms that was introduced in 2012 by the company Rethink Robotics. Unlike standard robots, Baxter can learn new tasks. After a human guides Baxter's arms through the motions of the task, it will be able to perform the task. Most impressively, Baxter can tolerate slop and mistakes in the process such as items not placed in the right location and dropping a tool it's holding. In this sense, Baxter can learn and adapt to its environment. Compared to the standard robotic system, we see both static, rigid intelligences and dynamic, malleable intelligences.

Or so we say. Can this "dynamic" intelligence actually learn anything? To answer using our example, no, Baxter can't learn dynamically. Baxter is designed for material handling in industrial environments – to humans, a low-skill job – and subsequently would not need to possess the cognition necessary for, say, cooking; a superbly difficult task. Baxter possesses what is known as constrained artificial intelligence, in that it can only solve a certain class or subset of



Robotic arms like this one currently work alongside humans in modern factories.



Can bunches of wires really learn as quickly as humans? Those who study artificial intelligence seem to think so.

problems. These intelligent systems are finding broader applications in the form of autonomous (self-driving) cars. Compared to Baxter, an autonomous car has intelligence that is much less constrained (the car must navigate a wider set of challenges), but still has limitations (the car still cannot cook a meal). When an artificially-intelligent system can operate at par with humans, the system can be said to possess general artificial intelligence. A general artificial intelligence is entirely feasible; even back in 1956, pioneering AI researchers at a conference at Dartmouth College proclaimed that "every aspect of learning or any other feature of intelligence can be so precisely described that a machine can be made to simulate it." Another way of putting that statement is: if a human can learn it, so can a machine. While a truly general artificial intelligence does not yet exist, the puzzle pieces which will eventually complete that enormous puzzle are being built right now.

> **"...the biggest concern with robotics is them taking jobs away."**
> **- Professor Michael Zinn**

Even systems of constrained intelligence such as Baxter and autonomous cars will leave an impression on the future. In fact, the autonomous car may well be looked at as a pivotal moment in the history of humanity. "I'm just amazed at how fast [the autonomous car] has gone from something that seemed impossible to something that is practically here already," says Professor Zinn. Even for a person who researches robotics for a living, the development of the autonomous vehicle comes off as incredible, exploding within the last fifteen years. According to members of the Institute of Electrical and Electronics Engineers (IEEE), autonomous cars aren't expected to capture 75% of the vehicle market until 2040. However, their imminent arrival could lead to the elimination of many of the taxi and semi-truck drivers in the United States.

But is the elimination of driving and, more broadly, low-skill jobs really a bad thing? For sure, the nostalgia surrounding manual driving will remain strong, and some will remain adamantly opposed to relinquishing the exhilaration of the open roads. "I think the biggest concern with robotics is them taking jobs away," Professor Zinn says. "And they do. From a macroeconomic point of view they don't, but locally they certainly do." As society has advanced and more opportunities arose, the occupation of semi-truck driver has experienced a severe decline in applicants. This shortage of drivers, coupled with the highest rate of work-related deaths (according to a Bureau of Labor Statistics report, 835 drivers experienced fatal injuries in 2014) will force the trucking industry to increase the adoption of autonomous semi-trucks whether they like it or not. Definite economic and societal concerns exist when companies replace workers with robotic systems, but the elimination of low-skill jobs could force society to pursue higher opportunities. While robotics may eliminate jobs, they are jobs society is rapidly losing interest in holding.

Technological progress may be disruptive, but it is progress nonetheless. Up until now, our robots augmented the assembly line, replacing workers with machines that perform repetitive tasks better than humans do. Robots will gain intelligence and self-governance, allowing them to make key decisions without our input. We humans, always vigilant and self-preserving, must ensure their applications strengthen, rather than damage, humanity. The same follows for artificial intelligence; as the current limited patchwork of AI coalesces into a powerful entity of general intelligence and self-governance, we must take care to guard that which is distinctly human while embracing the immense capabilities wrought by artificial intelligence.

Written by: Stephen Eick
Photography by: Tyler Parbs
Design by: Toby Sun

Perks of Being a Space Flower

Scientists are learning how space affects plant growth

In the scientific community, the plant Arabidopsis thaliana, related to the mustard greens family, is the lab rat of all plants. Because of its relatively small genome, it was the first plant to have its genome sequenced and since then has become a vital tool in research of the molecular biology of plants. So, this Eurasian native seemed the best candidate for a spot on a SpaceX mission to study plant growth in space.

In 2013, NASA sent 1,200 Arabidopsis seeds to the International Space Station, where they germinated and began to grow. Before anything else could happen, plant growth was chemically halted, frozen and returned to the lab of Simon Gilroy, a professor of botany at UW-Madison. Gilroy and his team proceeded to concentrate and purify the RNA of the seedlings, preparing them for the RNA Seek machine, which read and organized its 30,000 genes at UW-Madison's Biotechnology Center.

Before the partnership with NASA, Gilroy's team had been studying how plants respond to environmental stresses like wind, flooding, gravity and radiation. The researchers were trying to understand how plants detect and respond to these stressors. "For example, when a field gets flooded, the crops die because they run out of oxygen. But, they can last up to 3 days waiting for flooding to recede, where humans would last only seconds [without oxygen]," says Gilroy. Plants are aware of flood conditions and can sense when they are in a state of low oxygen. After identifying these environmental factors, the plants are able to defend themselves.

This research coincided perfectly with a problem Gilroy predicted NASA would run into when they recently grew red lettuce in the space station. Watering plants is no longer a fill-up-the-can-and-pour kind of job. Without gravity, the water will not pour or sink through soil. Gilroy says, "You can use a syringe and force water into the soil, but because of capillary forces, surface tension and adhesion, the water becomes sticky. So if you water a plant in space, the water will stick to and cover the roots, and a plant covered in water is flooded."

Another problem Gilroy was concerned with was how plants respond to cosmic radiation. Imagine a star exploding and its particles hurdling through space at near light speed. Cosmic radiation occurs when those particles pass other exploding stars and continue to accelerate, explains Gilroy. The Earth's atmosphere and magnetic field shield us from cosmic radiation, but the astronauts and plants in space are completely vulnerable, even in a space shuttle. Cosmic radiation can damage the astronaut's cells, and possibly cause cancer. However, space agriculture has also proven to lessen those effects. Antioxidants in blueberries and strawberries have proven to counteract short-term cosmic radiation in rats, which explains the red lettuce (also high in antioxidants) that was also recently cultivated on the space station.

The goal of growing Arabidopsis in space was to compare its 30,000 genes, profiled by the RNA Seek machine, to those of and Arabidopsis plant grown on Earth. Gilroy and NASA want to know which genes become more or less active in microgravity, and how plants can be engineered to thrive under these conditions.

Agriculture in space is imperative to sustain life for a long period of time, such as the eight month mission to Mars

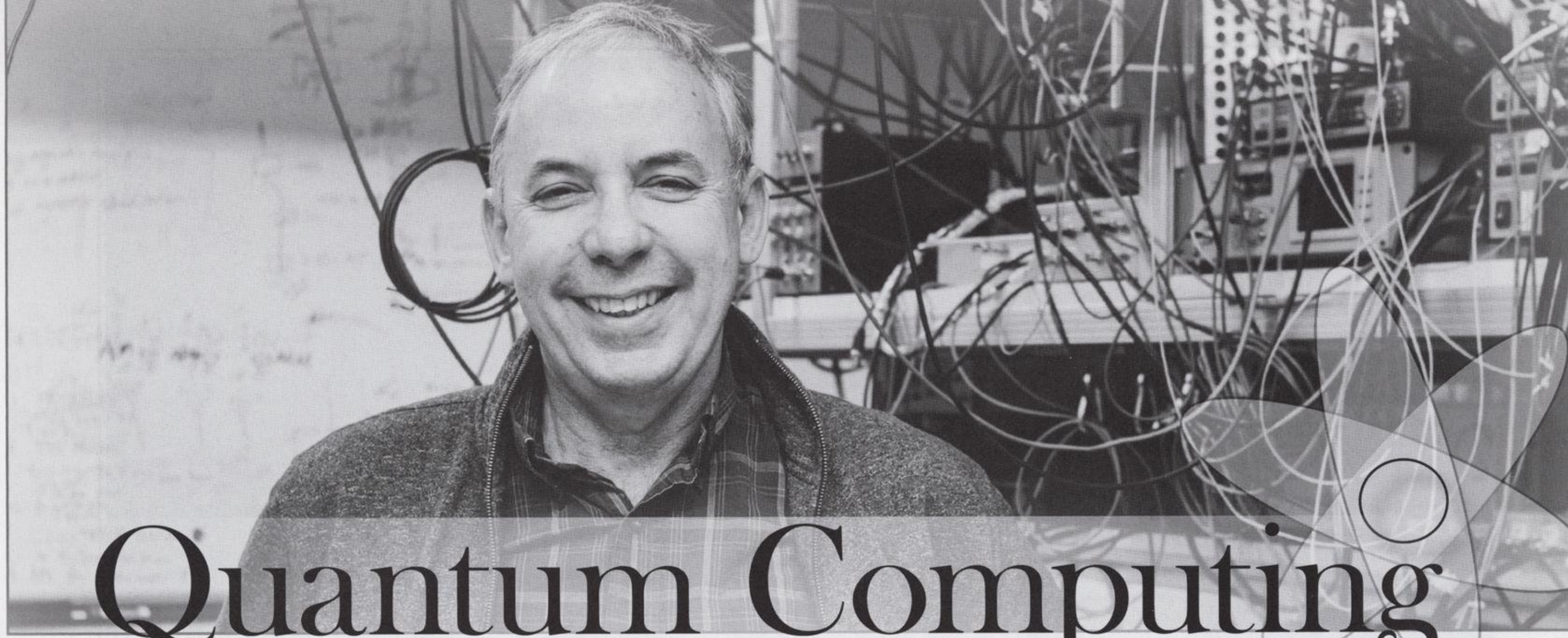
Agriculture in space is imperative to sustain life for a long period of time, like an eight-month mission to Mars. Available storage space is a currently limiting factor on small spacecraft, but would increase if astronauts didn't have to store freeze-dried food packets. Packets of seeds are much more efficient to store than the food packets, and plants that reproduce can supply endless nourishment long after food packets run out. A potato plant engineered to endure harsh space conditions may be the difference between a successful mission and starvation. NASA and Gilroy are working tirelessly to discover the secret of a plant's relationship to its environment in hopes that when the time comes for a Mars mission, the astronauts can bring a little piece of Earth along with them. WE

A full size plant of *Arabiodopsis thaliana* modeled in front of the LED display of a testing device, which emits wavelengths ideal for plant growth while testing.

Written by: Madison Knobloch

Photography by: Beth Enright

Design by: Pooja Shah



Quantum Computing

The future of computing might not be so "big" after all.

Computers have become an integral part of our society today. From the daily routine of the workplace to the technology behind automobiles, everywhere we go and everything we do seems to involve a computer. And, as our dependency on technology continues to expand, our need for more innovation only grows. While our computing power continues to increase according to Moore's Law, doubling approximately every 2 years, this trend cannot continue without our computer technology reaching the atomic scale. This is where quantum mechanics comes onto the scene.

Imagine a computer that can teach your phone to recognize any object it sees, or one that can instantly find the ideal route for thousands of planes to avoid hazardous weather, or one that can search through millions of social media posts to identify a potential terrorist. Classical computers can't crunch that big data without being given large amounts of time. But scientists have long theorized that a computer that could harness the principles of quantum mechanics would be able to perform these kinds of calculations quickly and efficiently, and even solve problems that would take years for a normal computer to churn through.

Mark Saffman, a professor of physics at the UW-Madison, is researching this intersection between computing and the quantum realm. Whereas digital computers require data to be encoded into binary digits (bits), each of which is always in one of two definite states (0 or 1), quantum computers use quantum bits (qubits) for data storage, which can be a superposition of these states. This means the qubit can be 0 and 1 at the same time. With this fundamental difference, by the time you get to few hundred qubits, the difference in computing power is enormous between parallel computations in a quantum computer compared to its classical counterpart.

While the concept of quantum computing is not a new notion, this is an exciting time for the technology. There has recently been a paradigm shift in the field as large companies are beginning to invest in quantum computing, including powerhouses like Microsoft, Google, Lockheed, and others. Saffman suggests that these big companies are investing because they are major players in computing, and they want to stay abreast of what might be an important development. So just how close are we to having a quantum computer? "It's all speculative at this point," Saffman says. "You can ask top researchers when there will be a practical quantum computer, and it all depends what you mean by practical."

This is, in large part, because quantum computers are very specialized. They aren't going to replace our classical computers; it's simply not going to happen. Simple tasks like using Word or checking email aren't going to be enhanced by using a quantum computer. However, there are certain problems we face today that would be much faster to solve using such a machine. "One of the applications of quantum computing that looks not that far away is something called quantum chemistry," Saffman says. This involves looking at molecules containing some number of atoms, understanding their internal structure, the energy levels, how they interact with each other. "This is something that chemists do all the time, Saffman explains. "They calculate things about molecules, but there's a limit to how large of a molecule they can analyze. The [classical] computers just don't have enough oomph. They need quantum computing to do that." Detailed studies have been conducted about the possibility of using a quantum computer to analyze molecules. If the quantum computer had just a few hundred bits, the prediction is that it could begin to solve problems that chemists cannot solve with the technology available today.

The issue here, though, is fidelity: how reliable do those bits have to be? Saffman clarifies, "The problem is that it's not just having a couple hundred bits, but those have to be really well performing bits that are corrected against errors." In a classical computer, there is hardware that corrects for various faults. There is always a correction going on in the background. According to Saffman, it will also be necessary that quantum computers contain this extra correction hardware. However, the error correction in the quantum computer is actually much tougher than in a classical computer. Roughly speaking, in the classical computer, the addition of one or two bits per byte lets you check and correct errors. "It's sort of a 10 percent or 20 percent overhead in a sense," Saffman points out. In a quantum computer, though, the overhead, or additional qubits needed for error correction, is more like a factor of 10 or a factor of 100. In order to have one really well-performing, reliable, non-error quantum bit or logical quantum bit, you might need 10 or 100 physical qubits. Thus, in order to solve these quantum chemistry problems that require approximately 100 bits, over 1000 qubits might be necessary in order for there to be the 100 logical

> **"In terms of the number of quantum bits that we can actually measure and control, I actually think that here, in my lab, we have the largest that anyone has done."**
> **-Mark Saffman**

quantum bits that are needed. "But, if researchers can get to that size," Saffman says, "then they could have something really quite revolutionary in computing."

In an effort to create a quantum computer of this magnitude, researchers are developing the machines using a handful of different approaches. The leading approaches use superconductors, semi-conductors, diamond, neutral atoms, charged particles, or photons as the platform of the computer. Each approach has its own pros and cons. The superconductors function with 99.9 percent reliability, as do the charged particles known as "trapped ions", but it's not clear at this point in development how to scale up the machines. The semiconducting approach isn't working extremely well in terms of reliability or scaling, either. Using light—photons—also has a great deal of scaling challenges. The difficulty with scaling in these approaches is due to, in simplified terms, the fact that the interactions can't be turned on and off. The ions have charges and they are always interacting, and because of that, it makes it difficult to scale up since the unwanted interactions would only increase. The superconductors, as mentioned above, also have other unresolved issues. In the superconducting approach, researchers have to send wires down to control each one of the qubits, and wires are problematic because while every wire sends the necessary electrical signals up and down, each wire also produces heat. This is a problem because the superconductors only operate in an environment merely 10 milliKelvin above absolute zero. There is also cross talk, or interactions, in the wiring that creates additional problems.

Professor Saffman is researching the neutral atom approach to quantum computing. "What's special about the neutral atoms, which is a positive feature," he says, "is that we can turn the interactions on and off." This allows for the neutral atom approach to be scaled relatively easily, but the fidelity of the qubits is still an issue. Qubits are extremely tricky to manipulate, since the slightest disturbance causes them to fall out of their quantum state (or "decohere"). This decoherence is the Achilles heel of the neutral atom approach and quantum computing in general. "In terms of the number of quantum bits that we can actually measure and control, I actually think that here, in my lab, we have the largest that anyone has done. We have a 2D array of 49 qubit sites, so we have up to 49 qubits. And that's more than anyone else has demonstrated," Saffman says. The downside is that those qubits aren't working that well. Right now, researchers at UW-Madison can entangle them, they can perform data operations, but their entanglement is only about 75 percent correct according to Saffman. Entanglement is an extremely strong correlation that exists between quantum particles that allows them to be inextricably linked in perfect unison, even if separated by great distances. This is what allows for the simultaneous calculation in the quantum computer. Some approaches have more control over this interaction, others have more fragile qubits; it's all about finding a balance between coherence and control.

So what exactly is the next step in quantum computing? Saffman says, "A bit further along, we'll see a combination of both industrial investment and government-funded research for the next generation of devices." If you look at computing today, a mature and well established industry, companies are investing in how to make the next generation of computers perform better in various ways, while at the same time other government programs are looking at high performance computing or computing with fast communication rates to solve particular problems; there's a mix of investment occurring. Saffman believes that will be the case with quantum computing, too. Today, though we are entering the phase of company investment, we are very far from having general-purpose quantum computers available commercially. Because the development of actual quantum computers is still in its infancy, for the foreseeable future, it'll be primarily government funding, and at some point will transition over to being more of an even mixture of investments.

Here at UW-Madison, research in this field is continuing to bring about innovations. Professor Saffman's team has a design for a 121-site qubit array that he expects will be put in place later this year. However, their main focus is getting the 75 percent fidelity up to 90 percent or higher. "Fidelity," he says, "that's really our main focus. There are some technical improvements we are about to put on our setup. We have ideas of what is causing the issues; now we need to go through the list, check them, and try to fix them."

Quantum computing has shown sizeable growth nationally and internationally, but also specifically here at UW-Madison. "Fifteen years ago," Saffman recounts, "there was basically no activity in quantum computing." Now there are 5 different faculty members involved and more than 20 students working in different quantum computing-related research. UW-Madison is rather unique in that we have 3 different experimental approaches being studied here: neutral atoms, semi-conducting qubits or quantum dots, and super-conducting qubits. There is external funding of more than $5 million per year coming into the physics department. Quantum computing is not only a huge part of this university, but is also growing across the globe, and it's only expected to get bigger—or is it smaller? WE

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Photography by: Ben Chen

Design by: Brent Grimm

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