GEORGIA TECH

ENGINEERS

VOL. V ISSUE II

SPRING 2018

ENGI-NEER-ING A TO Z

$$V_{load,rms} = \sqrt{\frac{1}{T}\int_0^T V_{load}^2 dt}$$

$$\eta = \frac{P_{out}}{P_{in}}$$

$$V = IR$$

$$P = \frac{V^2}{R} = I^2 R$$

$$L\{\delta(t - t_0), t_0 \geq 0\} = e^{-st_0}$$

$$R_1 || R_2 = \frac{R_1 R_2}{R_1 + R_2}$$

$$J_N = \mu_n n \nabla F_N$$

$$e_2 = -N_2 \frac{d\varphi}{dt}$$

$$X(j\omega) \triangleq \int_{-\infty}^{\infty} x(t) e^{-j\omega t} dt$$

From **THE DEAN**

Dear Friends of the College,

It's only been six months since I became dean of CoE. I still wake up every morning full of awe and gratitude that I get to lead what is arguably one of the best colleges of engineering in the country.

As my wife, Mary, can attest, the last few months have rushed by in a whirlwind, leaving a wake of papers, post-it notes, phone calls and handshakes. And I've loved every minute of it. I have met some amazing alumni, faculty and friends of the College — but most importantly — I've had the opportunity to get to know some of our brilliant students. They come from all walks of life, many driven by innovation and the hunger to invent. The bright young minds that fill the quad, classrooms, labs and libraries are what we're all about here at CoE.

I am very proud of some of the initiatives that have recently begun at the College. First and foremost is a recent $15 million commitment from the A. James and Alice B. Clark Foundation to launch the Clark Scholars Program in the College. This is the largest endowment for scholarship support the College has ever received. The investment will help incoming students who exhibit strong academic potential, leadership skills and financial need. This will allow us to attract students whose potential is great, but who may lack the financial resources to become a yellow jacket.

Second is the phenomenal growth of CREATE-X, our student entrepreneurial program. When CREATE-X started in 2014, 59 students took part. This fall, that number increased to more than 1,100. Fifty-three startups have come out of the program, with a total valuation of $100 million for all startups launched. Our ultimate goal is for CREATE-X to touch 100% of all Georgia Tech students, as well as to launch 300 startups a year. That would make us the largest startup campus in the country. Given the meteoric rise in student entrepreneurship, these numbers are not out of the realm of possible.

The Clark endowment and growth of CREATE-X speak volumes about our most important commodity — our students. We remain committed to attracting the best and most talented students, regardless of economic status. And to be able to equip them with the tools to succeed in business and life is at the very heart of what we do.

We have big plans for both the Clark Scholars Program and CREATE-X in the coming months — and I'll keep you updated on our achievements. Given the caliber of our students, I know there will be many.

Thank you for all the support you provide the College, and do stay in touch.

NICK BURCHELL

Steve McLaughlin
Dean & Southern Company Chair
College of Engineering

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ENGINEERS

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WELCOME to the issue

Spring is in the air at Tech. The hive hammocks are full of students relaxing in the sun. Even more people are lined up at the Tech Lawn food trucks to take advantage of an al fresco lunch. Students are choosing to study outside on the garden roof of Clough, rather than inside the library. And of course, the azaleas and dogwoods are in full bloom.

We've been hard at work on our Spring issue for months. It happens to be a special issue this time: Engineering A to Z. You'll notice that instead of our regular news briefs and feature articles, we've hand-picked a compelling engineering topic for each letter of the alphabet.

Engineering A to Z has taken us all over Tech's campus — we took the trolley up to Tech Square, and even went across town to Emory. And within these pages, you'll read about topics that have an impact on our lives, like predictive healthcare and traffic calming. You'll learn about brilliant engineering students who are creating concrete canoes and all-natural herbicides. As always, the great minds of our faculty are showcased throughout the issue — from cloaking research to quantum dots to wireless 5G.

So, enjoy this journey with us from A to Z. Visit the labs across campus, where exciting inventions are created. And remember that at Georgia Tech, we can do that.

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COVER ILLUSTRATION: QUENTIN LUENINGHOENER

A is for ASCE'S CONCRETE CANOE

A rising tide lifts all boats, even concrete ones

by Polly Ouellette

Concrete doesn't float. But that seemingly obvious fact doesn't stop hundreds of teams at colleges around the country from building and racing concrete canoes. The concrete canoe challenge is part of an annual competition that involves every chapter of the American Society of Civil Engineers (ASCE), including the one at Georgia Tech.

Teams build canoes from scratch, adhering to unique annual rules about the design and specifications of the canoe. One year, students couldn't use paint. Another year, the canoe's curvature had to fall within certain specifications. Recently, students were restricted on the materials they could use to make the canoe.

The first competition is usually in April, but preparation begins months before.

STEP 1: AUGUST Basic design on the computer comes first, then alterations are made once the rules are released. An aerodynamic design is essential so that the canoe can cut through water.

STEP 2: SEPTEMBER Next is the concoction of the concrete recipe. Traditionally, concrete is made up of three components: cement, water and aggregates, which are usually pebbles or rocks. But traditional concrete doesn't float, so Georgia Tech's concrete canoe team has to get creative.

"Obviously, the canoe has to be light enough to float, so instead of using rocks as aggregate, we use these hollow glass bubbles," said Michael Waters, the captain of the concrete canoe team and a fourth-year civil engineer. "They are much, much lighter than water, and that lets the canoe float."

The concrete is formed into cylinders and placed under intense pressure until it breaks, which tells the group how strong it is and lets them make adjustments to the recipe. The canoe has to hold up to four people, so it has to be not only light, but also strong.

STEP 3: JANUARY When it comes time to make the actual canoe, the team heads over to the Digital Fabrication Lab in the College of Design and cuts large foam blocks into the curved shape of the inside of a canoe. These blocks are turned upside down, and the concrete is mixed and poured over the blocks as a shell. After the concrete dries, the blocks are removed and a fully formed canoe remains.

STEP 4: MARCH Not only must the canoe float, but students have to race it. Waters and his teammates head to nearby Lake Lanier or Lake Acworth to practice paddling the canoe before the competition.

"It weighs infinitely more than any regular canoe," said Waters. "The steering, especially, takes a lot of getting used to."

When it's time for the race, there are speed and endurance categories, as well as technical design and presentation divisions, which are judged by a panel of civil engineers. Any violations of the

rules, like using too many glass bubbles, can result in point deductions. Waters says that the Georgia Tech chapter is especially good at the technical categories.

Through the process of designing, building and racing the canoe, Waters says that everyone really gets to know their classmates.

"I think the main goal is applying what you learn in the classroom to a fun project," said Waters. "If you can have fun and learn at the same time, that's what it's all about." ▪

Above: The canoe team prepares for the women's sprint race. Credit: Vy Le.
Right: Applying the concrete to the canoe form during the construction process. Photo courtesy Georgia Tech ASCE.

B is for BIG DATA

In his words: Sebastian Pokutta on big data getting bigger – and what it all means

by Sebastian Pokutta

CRAIG BROMLEY

Big data will finally reach maturity when you don't see it. It will be everywhere in our lives, but it'll be invisible. That's where data is heading.

Right now, we're at a stage where the information is there, and we're trying to figure out what to do with it. People believe data is money, so most companies are harvesting data in very aggressive amounts. But so many companies still don't know what to do with it. Google, Facebook, Microsoft and Instagram — those are the places where the business model is based on data. But, not many others have figured out how to work with it. The data is stored in different places, it's not actionable, or it's in an unstructured heap.

So, companies can get paralyzed by the huge amounts of data. And if there's a company not already working effectively with big data, it's hard to hire top talent, because the top talent wants to go to Google and Facebook. Few are interested in working on machine learning and big data at a traditional, brick-and-mortar business.

And there's a more fundamental thing: The companies that want to get into the game should hire a head of innovation who hasn't been trained in, and doesn't conform to, conventional standards. The worst thing these companies can do is miss the opportunity to hire a risk-taker as head of innovation simply because he or she would not conform to the typical board- and chairman-approved codes. You have to aggressively hire top, young talent for leadership positions to get ahead and to make innovation a key component in the corporate DNA.

For example, Macy's understands that big data innovation is critical for success. They've sponsored various big data projects at Georgia Tech, and we designed solutions for their needs. One solution was prepackaged inventory, or using data to predict what people will be ordering, so that they can pre-package the items and then slap an address label on them.

This helps balance worker demand. At peak times, they're sending, and in slow times, they're packaging.

When you have erratic demand, you want to avoid having your workers busy one day, but not the next. You want to reassign workload.

Where's it all going? The only reason businesses collect all this information is to make decisions. In the future, you'll see more autonomous systems as you go through your day. They'll be processing very large amounts of data immediately to make decisions for us. ▪

Sebastian Pokutta works at the intersection of theoretical frameworks and practical applications of big data. As the David M. McKenney Family Associate Professor in the Stewart School of Industrial & Systems Engineering (and an associate director of Georgia Tech's Center of Machine Learning), he has led more than two dozen research projects in big data, machine learning and optimization with a wide range of companies.

C is for **CLOAKING**

With metamaterials, hide-and-seek gets high-tech

by Desirina Frew

From Harry Potter's invisibility cloak to Wonder Woman's invisible plane, fiction offers a glimpse of the potential future. It's intriguing to imagine something that's present and real — yet can't be detected.

But "cloaking" is not just fiction; researchers have been working on it for years. While a lot of the work has focused on bending light to hide objects from view, Georgia Tech engineering faculty are venturing beyond and exploring other forms of invisibility. Here are three examples.

A CLOAK OF SILENCE FOR A CITY CONDO

Imagine your neighbor had a rock band, and when they practiced in the garage, you wouldn't even know.

That's the kind of real-life situation Martin Maldovan is working to create.

An assistant professor in the School of Chemical and Biomolecular Engineering, Maldovan is exploring how to develop acoustic cloaking that bends a sound wave. It's a form that uses "metamaterials," which interact with physical phenomena in unnatural ways. The metamaterials are created by arranging individual atoms of plastic, glass or metal into nano and microscale structures, and then building materials from them.

Typical soundproofing is achieved through materials that absorb sound waves. But cloaking would use a metamaterial that sound waves don't affect — the waves would flow around the material and meet, unaffected, on the other side.

An "outer shell" of this material could hide noise generated outside a building. Your neighbor's band could turn the speakers up, with no complaints from you.

CLOAKING NITROGEN SAVES ENERGY (REALLY!)

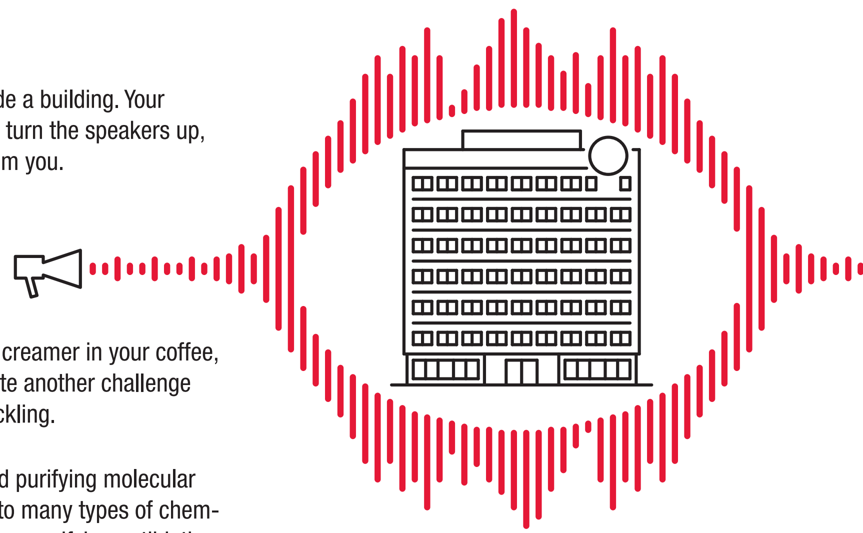
If you can imagine having to "unmix" the creamer in your coffee, then you can appreciate another challenge Martin Maldovan is tackling.

Sorting, separating and purifying molecular compounds is crucial to many types of chemical engineering, such as purifying antibiotics, refining fuel or growing semiconductors on crystal. One common method uses many rounds of evaporation and distillation. But at industrial scale that requires extraordinary amounts of energy — which is expensive and harmful to the environment.

Maldovan has discovered a novel and efficient way to separate a blended substance into its original components, while using much less energy.

He engineered a metamaterial shell to direct the path of atoms, sending oxygen into the core of the shell and nitrogen around it. The nitrogen is "cloaked" because it's immune to interaction with the core of the shell, which only grabs the oxygen atoms, separating the mixture into its component parts.

Following the success of his prototype, Maldovan is exploring ways to optimize the design, using different polymers to produce the metamaterial and targeting different compounds for separation.



QUENTIN LUENINGHOENER

ONE DAY: A BUILDING CLOAKED TO WITHSTAND EARTHQUAKES

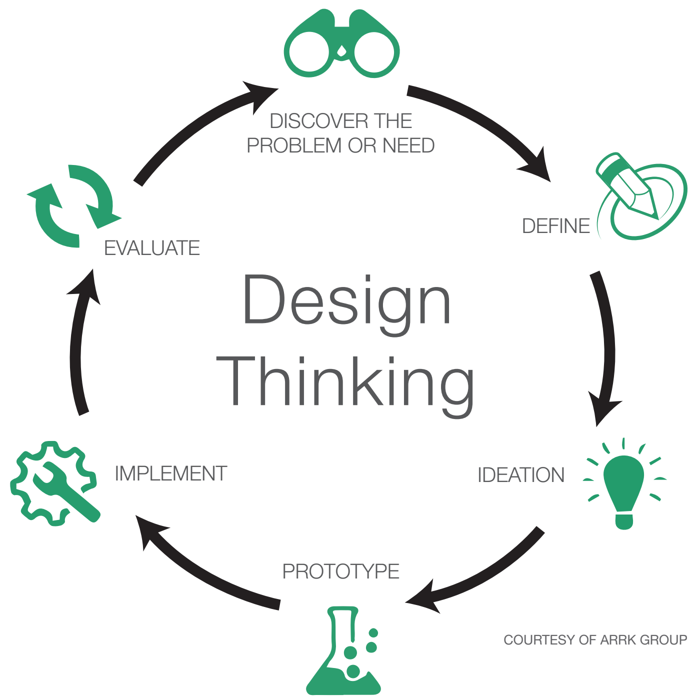
The damage by earthquakes, and even explosions, comes in the form of stress waves, or, vibrations that transfer energy through the earth from its original source. Arash Yavari, a professor in the School of Civil and Environmental Engineering, is working to lay the theoretical groundwork for cloaking buildings from such stress waves to shield them from damage.

"We could change the way we design foundations," says Yavari. "When a stress wave hits, this engineered material would deflect and redirect the wave."

In a sense, the building would trick the wave. Like the sound waves in Maldovan's research, these stress waves would flow around the building … as if it wasn't even there. ▪

D is for DESIGN THINKING

Students focus on the user when designing their solutions



COURTESY OF ARRK GROUP

by Polly Ouellette

Design is creative. Interior designers decorate rooms in a house. Landscape architects arrange gardens and pools. But design thinking takes this broad concept of design one step further. It's a skill that involves constantly evaluating the world around you to creatively solve problems. Amit Jariwala, director of design and innovation in the Woodruff School of Mechanical Engineering, says that the key to great design is to keep the focus on the user when coming up with a solution.

"If you really drill down into the problem and put the user in the center, then you can start to think of creative and innovative solutions," Jariwala said. "It's not about using complex and sophisticated technology. Rather, the process of design is hinged on evolving to a clearer state of problem understanding. A good designer spends more time thinking about who the end user is and what that user needs than being fixated on how to use a specific solution."

Jariwala works with a large team of faculty responsible for making sure Tech's engineering students are exposed to design thinking right from the start. It takes practice to learn this particular brand of problem solving. Freshmen learn drafting and computer-aided design through some hands-on experience with digital fabrication, and students are given their first real design project sophomore year.

The design process starts with an evaluation to determine the problem. Design is more of a diverging and converging cycle than a linear path, which can be tricky for students to figure out. Unlike typical engineering course assignments, design projects do not easily lend themselves to a deterministic right or wrong answer. Students must have an active imagination as they explore all solution directions, and they must be focused as they zero in on a feasible solution. However, before proceeding with that solution, countless more decisions must be made before they settle on the final design of their product.

The culmination of design thinking instruction is the Capstone Design course that challenges students to solve real-world problems with the guidance and support of industry sponsors. Every year, more than 1,800 seniors from the College of Engineering demonstrate their creative projects at the end-of-semester Capstone Design Expo.

"We challenge our Capstone students to work collaboratively, and across disciplines, to address problems at the macro level," said Jariwala. "The design process, which involves systematic, yet iterative problem solving, requires students to step back and determine what knowledge is needed to solve the problem."

The systematic application of the design process leads to innovation. Georgia Tech students are using their design skills to invent new solutions and build startups. Successful teams from Capstone Design and other innovation-focused programs, such as the InVenture Prize Competition, have transformed their projects into profitable businesses or impactful solutions.

For example, this year's Georgia Tech InVenture Prize winner was Kolby Hanley, a third-year materials science and engineering student and the creator of an invention called Starlight. The 3D-printed gadget helps competitive archers aim more precisely. Another winning team created a device that tracks the vitals of firefighters — it's a wearable for firefighters that monitors, records and displays real-time biometric information.

Jariwala says that no matter what career path a student ends up pursuing, they will use design thinking; whether they engineer an electric car or envision the optimal infrastructure for a city, the process is the same. ▪

E is for EXOSKELETON

Prosthetic outerwear helps patients take the next step

by Polly Ouellette

While 'exoskeleton' conjures up images of insects, the concept is being applied to human mobility at Georgia Tech, where researchers are helping people regain the ability to walk. Rigid structural elements — reminiscent of the armor of a beetle — are helping people with injury or disease affecting their limbs to regain some of their mobility.

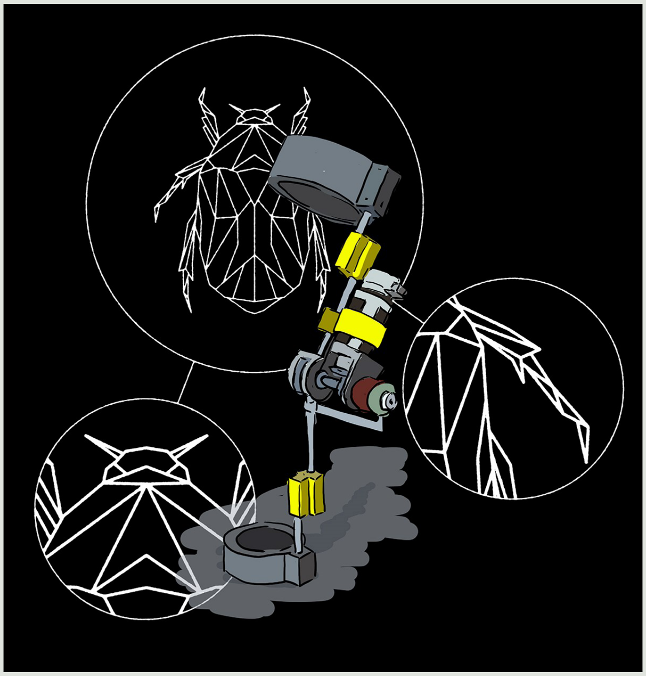
The Exoskeleton and Prosthetic Intelligent Controls (EPIC) Lab in the Woodruff School of Mechanical Engineering uses exoskeletons to promote mobility in patients who have suffered from a stroke, muscular dystrophy or other motor control impairments. Most of the patients who are seen by the lab have their limbs intact, but need help to retrain their bodies to walk, run and climb stairs.

The exoskeletons are motor-controlled, which means they use active force to help a patient bend and extend their knee, for example. Lab researchers must find the ideal way to attach an exoskeleton to a person via straps, metal bars and plastic pieces at the correct position to create the perfect stand-in for a joint. Once the exoskeleton is attached with sensors in order, then the device can effectively improve the user's mobility.

However, the research doesn't stop at simply using motors to assist movement. The focus and biggest challenge of the EPIC Lab's research is sensing exactly what a patient is trying to do at a given moment and manipulating the motors in the exoskeleton so that they apply just the right amount of force at just the right angle.

"How do we detect what the user wants to do and then translate that into a set of robotic commands to provide the proper amount of assistance for movement?" asks Aaron Young, an assistant professor of mechanical engineering who leads the EPIC Lab. "Commands through that control system interpret a high-level goal like, 'I want to walk a little bit faster' all the way to actuating the different motors correctly with the right amount of power to do that task."

This process begins with sensors that capture a person's movements and body positions. One of the more complex sensors uses electromyography, which reads the electrical signals that muscles generate. If an individual intends to take a step, their nervous system will send signals down through the nerves to the muscles that will need to move in order to take that step. Surface electrodes on the skin read the voltage of the electrical signals that the muscles generate.



QUENTIN LUENINGHOENER

"We can sync the exoskeleton torque to correspond directly with the muscle forces that the person generates," said Young. "This is a promising technique because it allows the exoskeleton to respond to the person's movements in real time."

The next step in the rehabilitation process is using machine learning algorithms to recognize the unique patterns an individual uses to walk. Eventually, the exoskeleton will be able to predict when the patient wants to do something, like stand up from a chair, a seemingly insurmountable obstacle for someone with limited mobility.

With time, exoskeletons will become more advanced and more effective in helping people return to being active and mobile in their communities. ▪

F is for **FABRIC**

For Under Armour, mystery solved

by Desirina Frew

When an athlete slides across the surface of a hardwood court (think basketball or volleyball courts), it can cause a wardrobe malfunction: a small tear in the player's clothing.

But what exactly causes the tear? Why does it happen at some times but not others? And how can it be prevented?

These questions stumped sportswear maker Under Armour, one of Georgia Tech's College of Engineering's industry partners. The company wanted to ensure its garments were durable, with high-quality fabric that wouldn't shred under pressure. Under Armour explained the problem to a team of materials engineering students, who decided to tackle the challenge for their senior design project.

When they showed their preliminary work to textiles Professor Mary Lynn Realff, she knew they'd discovered something fascinating. The fabric wasn't tearing; it was melting. Realff's own work focuses on the mechanics of woven fabrics. She explores how textiles work at the micro level, like exploring how fibers threaded with carbon nanotubes can affect durability and strength.

So, she knew the students' findings were the real deal. "I realized the students could develop this into a peer-reviewed paper," she said.

The students designed and built a testing apparatus they called "the Fabric Pendulum Abrasion Tester." The device reliably replicated the real-world melting effect in the lab, allowing them to examine the elusive piece of the puzzle. The students analyzed how 11 different types of athletic fabric responded to friction. They also created a thermodynamic model to illustrate how friction heat melts fabric, which was supported by data from heat sensors in the Abrasion Tester.

One of their key findings was that the type of fiber in the fabric matters less than the structure of the fabric. So, polyester versus nylon fabric, for example, is less important than the pattern of the fabric's knit or weave.

Under Armour was so impressed, they invited the students to continue working on the project over the summer.

"We really value the opportunity to help students prepare for their careers by creating challenging real-world problems that we can work together to solve," says Matthew Trexler, director of technology validation for Under Armour. "It can also help us better understand our products."

With the testing method the students developed, the company can develop more durable athletic wear that will stand up to the wear and tear of sports. ▪

QUENTIN LUENINGHOENER

One of their key findings was that the type of fiber in the fabric matters less than the structure of the fabric. So, polyester versus nylon fabric, for example, is less important than the pattern of the fabric's knit or weave.

G is for GOOGLE

David Frakes says it's a special place to work

Interview conducted by
Michael Baxter

He earned four engineering degrees, kicked 26 field goals and pole vaulted over countless heights for Georgia Tech. Now, David Frakes (B.S. ECE 1998, M.S. ME 2002, M.S. ECE / Ph.D. BME, 2003) is helping Google find new ways to engage consumers.

Frakes took a few minutes out of a busy Friday at Google's Mountain View campus to chat with Georgia Tech Engineers.

How did you end up a Googler? Google funded some of my work on array cameras and related computer vision when I was a professor at Arizona State University. Then they offered me a two-year appointment as a technical program lead. I was due for a sabbatical, so I accepted it. Google has some programs that bring in professors and other field leaders and empowers them to incubate technology. The model is to pursue something ambitious for two years — and sprint the entire time.

So, what are you working on for Google? I can't go into depth, but I lead a few teams that work on new ways of shopping. We look for opportunities to connect consumers with products in more meaningful ways.

You have four engineering degrees from Georgia Tech. How did that happen? I had planned to go to medical school. After finishing my undergraduate work and playing football, I found myself in a position where I had some eligibility left in track. I didn't want to move on until I used up that time, because track was really fun. There was no well-thought-out plan around how those degrees were sequenced. It was me following what I was passionate about.

So, if not for track, you might've taken a different path? There's a high likelihood I would've gone somewhere else. In the end, you can't do much better than a Tech degree, though.

How did your engineering education prepare you for your work at Google? A key thing I learned at Tech was how to take things from one field and apply them to another. That's served me well in solving cross-functional problems and prepared me to innovate. Georgia Tech made me who I am in that regard. I couldn't be more thankful for Tech as an institution.

Ever come across other Georgia Tech engineers in the hallway or break room? Oh yeah.

What's that like? Well, I have a number of Tech people I've hired here at Google who work on my team. When I came here for my first interview — which can be a challenging process, because a lot of smart people work here — the very first thing I saw was a Georgia Tech football helmet on someone's desk.

What's one thing about working at Google that would surprise people? How extremely hard everyone here works. Sometimes what you hear about most in the media are the perks — like people at Google are hanging out in the cafeteria and just living the dream. But with those perks comes an awful lot of hard work.

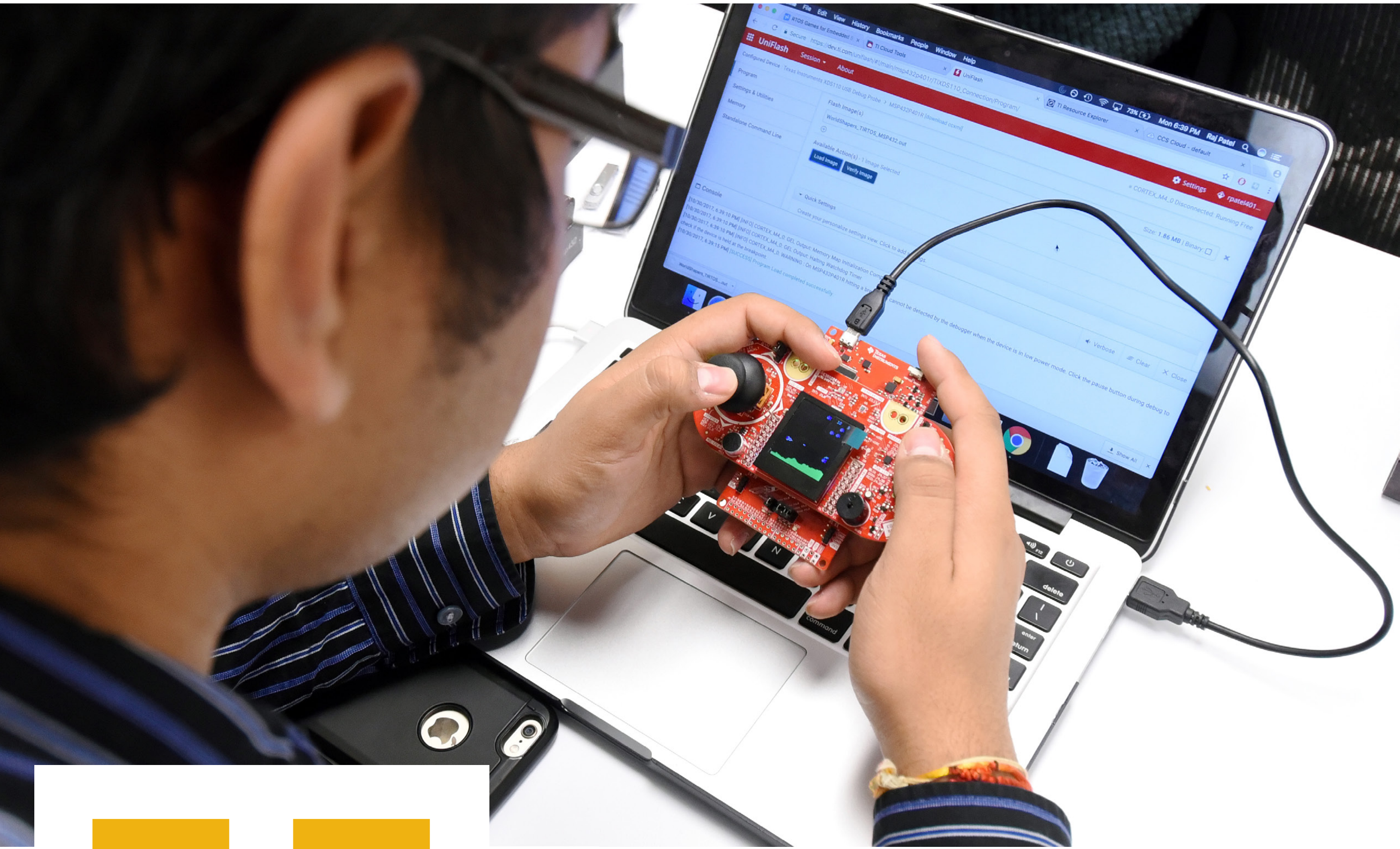
PHOTO COURTESY: DAVID FRAKES

We've heard Googlers can work on projects of personal interest outside of day-to-day responsibilities. That's absolutely true. There are several mechanisms to pursue your own interests. There are also opportunities for every Googler to spend 20 percent of professional time to grow and investigate new things. It may be with a new team, or it may be that you start an entirely new project.

Are you doing that? Not right now. I did a few times before, though, and that led to my current role.

How did placekicking for the Yellow Jackets prepare you for your career? You don't go through a career as a kicker without learning how to deal with pressure. In terms of experiences I've had here and in other places, the amount of pressure that makes me uncomfortable is high compared to the average. Going through very high-pressure situations on the field helps keep you balanced off the field.

Do you ever Google yourself? (Laughs.) No, I don't do that. ▪



GARY MEEK

H is for HIVE

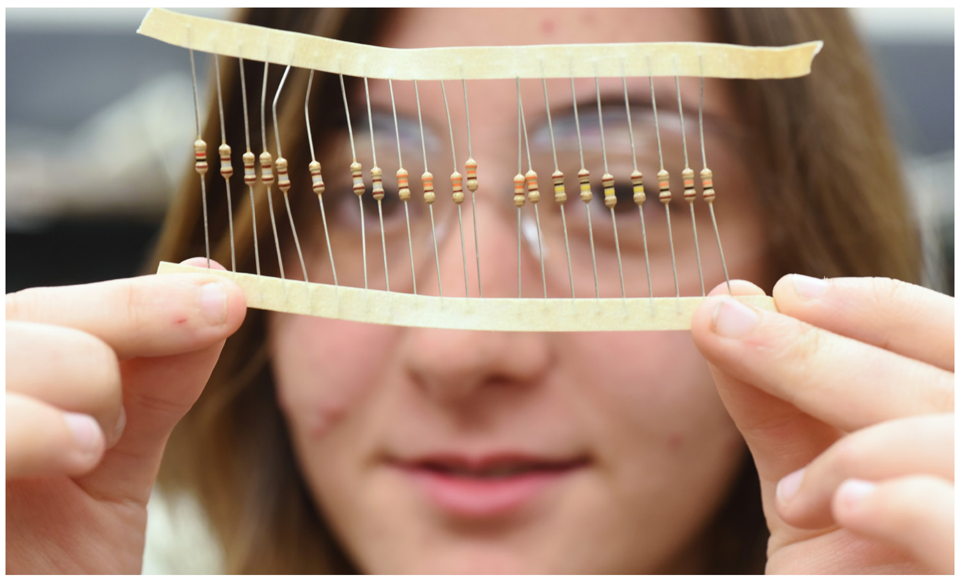
Electrical and computer engineering gets a space of its own

by Polly Ouellette

Although there are already a growing number of makerspaces on campus, students in Georgia Tech's School of Electrical and Computer Engineering (ECE) felt that there wasn't a dedicated space for them to conduct small-scale, delicate electrical work. So, a few students took it upon themselves to change that, and have formed a group known as "The Hive."

The Hive is working to staff a space where students of any major will be able to come and work on personal or academic projects with the guidance of the student instructors. The recently chartered student organization focuses on hosting workshops and instructional sessions in order to get students interested and teach them how to use the available equipment. Hiba Murali, The Hive's director of communications and a fifth-year computer engineer, was particularly fond of their Halloween event, which taught students how to make an illuminated jack-o'-lantern from a circuit board shaped like a pumpkin. "It's not supposed to be like a class where you come in and sit and watch the teacher," "It's not supposed to be like a class where you come in and sit and watch the teacher. We really want it to be hands-on, experiential learning on fun topics that interest students."

HIBA MURALI, 5TH YEAR CMPE



GARY MEEK

said Murali. "We really want it to be hands-on, experiential learning on fun topics that interest students."

Right now, The Hive gathers in a senior design lab with limited equipment and availability.

However, Tech is working on improvements that will fulfill a much larger vision of the ECE makerspace. The former Van Leer auditorium will be transformed into three floors of collaborative space for students. As the future home of the ECE makerspace, it will house a variety of equipment, the use of which will be supervised by members of The Hive. Other spaces in the building will include study rooms and lecture spaces designed to host visiting ECE professionals.

"We're hoping to create a student-friendly zone where people can come in and work on any project, and if they need help, it's available right there," said Murali.

The Hive is working to obtain even more state-of-the-art equipment to stock the ECE makerspace. Murali is especially excited that The Hive is getting a HoloLens, a virtual reality device that enables the wearer to visualize holograms that have been created via computer programming. To acquire new supplies, the students have been working with Kevin Pham, an electrical engineer in ECE who runs a materials repository. They hope to eventually have the materials necessary to create circuit boards, solder parts, or perform testing.

Companies like Lutron Electronics have generously donated time and resources, leading workshops in collaboration with The Hive and supplying the group with materials. Texas Instruments held a workshop on the Internet of Things, teaching students about the interconnection of computing devices, like microcontrollers, with everyday objects, like cell phones, so that they can send and receive data.

Beyond collaborating with industry leaders, The Hive plans to forge connections with other departments on campus and cultivate an environment of learning that is hands-on and allows every student to explore electrical and computer engineering. ▪

I is for INCLUSIVITY

Missing or invisible? Inclusivity conference is first step in NSF project to make engineering field more welcoming to LGBTQ+ professionals and students

by Georgia Parmelee

A paradigm exists within the engineering field, according to recent literature. It's that engineers think in binary terms, setting aside personal connections in favor of purely technical skills. Researchers have identified that the field as a whole is particularly masculinist and heteronormative, as well. For an LBGTQ+ individual (Lesbian, Gay, Bisexual, Transgender, Queer and others), this environment can be daunting and unfriendly, and often keeps them in the margins. Most LGBTQ+ individuals pass for heterosexual, cisgender individuals or cover their invisible identity.

Four Georgia Tech faculty members want to challenge the existing culture in engineering and promote inclusivity and diversity in schools across the country. Drs. Chloé Arson (School of Civil and Environmental Engineering), Jennifer Hasler (School of Electrical and Computer Engineering), Manu Platt (Department of Biomedical Engineering) and Anne Pollock (School of Literature, Media and Communication) are trying to understand why LBGTQ+ people are less visible in engineering disciplines than in other fields, even within STEM.

One of the core questions to answer is: Does engineering attract less LBGTQ+ students and employees because of its binary reputation? Or are they present, but just invisible?

To answer the question, the four professors received a grant from the National Science Foundation (NSF) with the goal of making LGBTQ+ individuals more present and visible in the engineering field. The grant provided funds to run a conference that brought together faculty from across the country to discuss how to attract more diversity in engineering, as well as collect metrics and data on invisible identities, like sexual orientation.

"Receiving this grant from the NSF is something very symbolic, and their support enhances our credibility," Arson said. "Our proposal was peer reviewed, and people will trust the results. The support from the NSF will put our work in the public domain and encourage other LGBTQ+ projects to get started."

Although it was discussed at length during the conference, there was no definitive answer as to why engineering attracts less LGBTQ+ students and employees. Or if they are in fact present, but invisible. More work will have to be done to make that determination.

"LGBTQ+ individuals' lives do not fit neatly into an engineering department," Pollock said. "It makes it difficult to negotiate being out because personal life and the technical aspects of the job are generally thought to be completely separate."

A few conclusions did come out of the conference. There was a common agreement that other aspects of identity also affect how LGBTQ+ faculty navigate the workplace, including gender, race and partnership status. Also, some longitudinal data was presented that indicated that over the course of a student's engineering education, they become less aware and interested in making a social impact. The grant's principal investigators recognize that these two areas will be important to study and address going forward.

Arson, Hasler, Platt and Pollock hope that the NSF grant will bring more attention to LBGTQ+ issues in engineering and help to develop an unbiased culture. Post-conference, they plan to develop a methodology for collecting data and create benchmarks for how the engineering field can be more inclusive. The exploration and research fostered by the conference is the first step to creating an environment that celebrates differences and ensures everyone is welcome. ▪

PHOTO COURTESY: WIE

J is for JUNIOR ENGINEERS

Young students come to Tech to learn what it means to be an engineer

by Polly Ouellette

When young children are asked what an engineer looks like, many of them draw a man conducting a train or a car mechanic, according to a study from Tufts University. The study concludes that many young people have a skewed understanding of who engineers are and what they do.

In the face of these common misconceptions, organizations across Tech's campus work hard to expose elementary, middle and high school students to real engineering and show them what it takes to study it. Women in Engineering (WIE) and the Center for Engineering Education and Diversity (CEED) are groups within the College of Engineering that focus on reaching different subsets of these students: young women and underrepresented minorities.

Both groups firmly believe that if children are exposed to science, technology, engineering and math (STEM) concepts early, they are far more likely to stay interested as they get older. Christine Valle, director of WIE, insists that middle school girls are the demographic group that is most in need of that inspiration.

"In middle school, it's been well-documented that there's a huge drop in interest in math and science for most girls," said Valle. "We want to at least expose more girls to engineering. Ideally, we'd like more of them to eventually choose engineering, both in college and careers, but at least we want to expose them to it, so that if they decide that this is not for them, they at least make an informed decision."

WIE organizes a variety of programs run for and by young women. They visit classrooms to introduce kids to female engineers, invite middle schoolers to hands-on summer camps and bring high schoolers to conferences that dive into what it means to have a career in engineering. All these events provide role models for young women.

CEED is also highly involved in offering potential engineers someone to look up to. The on-campus organization strives to show young people that they have the ability to succeed and help them do so.

CEED knows that the world needs more engineers, especially those from diverse backgrounds, and works on recruiting and retaining a diverse body of engineers by primarily targeting students who are traditionally underrepresented in STEM fields.

"We are trying to help cultivate the pipeline of engineers," said Jackie Cox, the programs and operations manager at CEED. "We are trying touch one life at a time, with one experience at a time."

CEED works to show students what it is like to solve real-world problems with engineering, and it also runs a variety of outreach activities, ranging from visiting a kindergarten classroom for a few hours to hosting the Summer Engineering Institute program on campus for three weeks. Cox says that while intensive programs like the Summer Engineering Institute can change a student for life, just a few hours of experiencing what an engineer does might be all it takes to catch a student's interest and keep them coming back for more.

Both Cox and Valle said that when they see junior engineers who attended a camp in middle school or came for an event in high school eventually attend Georgia Tech, they know they did their job well.

"You really get a sense of how kids develop and grow," said Valle. "You get to see in a real live person that what you do has an impact. I can say for a fact that I have a job where I am making a difference." ▪

K is for KOLON CENTER FOR LIFESTYLE INNOVATION

Researchers and industry experts partner to make bold ideas a reality

by Polly Ouellette

Soldiers in combat, firefighters in a burning building, and astronauts in space all need constant monitoring of their vitals to help identify on-the-job injuries and adverse health events. A few years ago, Sundaresan Jayaraman designed the Georgia Tech Wearable Motherboard (a.k.a. the "Smart Shirt") to monitor employees in the field. True to its name, it was one of the first wearable technology devices.

Today, after years of media attention and a variety of awards, the "Smart Shirt" can be found in the Smithsonian's National Museum of American History. Jayaraman's invention signified several technological breakthroughs; it was the first clothing item that could detect projectile penetration, as well as temperature, heart rate and respiration rate.

Through his "Smart Shirt," Jayaraman got his first taste of taking a technical-materials prototype to market. But, not every invention or idea makes it quite as far. Researchers can have trouble getting their groundbreaking products into industry due to heavy regulations, strict standards and lengthy processes.


QUENTIN LUENINGHOENER

That's where the Kolon Center for Lifestyle Innovation (KCLI) comes in. The partnership between Georgia Tech and Kolon Industries connects researchers with experts in industry to ensure that their technological discoveries will be transformed into real, usable products that have a lasting impact. Kolon Industries is composed of a group of Korean companies that make products based on advances in materials and manufacturing in order to improve the lifestyles of the people that use them.

"We are the catalyst between fundamental research, which we are great at here at Georgia Tech, and the company, which is responsible for making it into a product," said Jayaraman, now director of KCLI and joint professor in the School of Materials Science and Engineering and Scheller College of Business.

True to the center's name and the central goal of Kolon Industries, every product that goes through KCLI is focused on lifestyle innovation. Georgia Tech researchers and Kolon Industries have worked together, through workshops and discussions, to identify human-focused technological challenges and create strategies to overcome them.

The collaboration opens up doors for everyone involved to benefit. Researchers discover potential problems that arise when their proof of concept is tested against industry standards. Graduate students gain experience in presenting their work to technical experts, who ask tough questions and make impactful suggestions. Some of these students even get financial support for their research through the Kolon Undergraduate Scholars program.

The collaboration between industry and university has just started up, and already KCLI has received 18 proposals in their first year and has chosen to fund three. Jayaraman and his Georgia Tech colleagues are very proud of how far they have come already and are confident that KCLI will provide researchers the unique opportunity to see their work put to good use in many different industries. ▪


HELLUVA ENGINEER.
HELLUVA MBA.
As an engineer, you know that solving problems means tackling issues from every angle. At Georgia Tech Scheller College of Business, we equip you with the knowledge you need to tackle a whole new set of challenges, from operations and finance to commercialization and strategy. Our globally-ranked MBA programs feature specialized curriculum designed to prepare you to thrive in today's innovative, entrepreneurial world of business, all right here at the university you know and love. Learn more at scheller.gatech.edu.
TECH SAVVY. BUSINESS SMART.
Georgia Tech Scheller College of Business

If a turtle gets hit by a propeller at speed, whether it's at the surface or deeper in the water, it is likely going to have a catastrophic injury. Turtles struck by jet-driven watercraft or just the hull of a boat are likely to avoid serious injury and survive.

L is for **LOGGERHEADS**

Researchers protect turtles through engineering

by Joshua Stewart

A few years ago, the Georgia Department of Natural Resources (DNR) approached Georgia Tech civil engineers David Scott and Paul Work with a request.

It was, to say the least, unusual: Could they use structural and materials engineering principles to understand what happens to turtles when they're struck by boats? At the time, officials were seeing a spike in turtle deaths in the state's coastal waters, and they wanted to find ways to protect the animals, while balancing recreational and commercial use of the waterways.

Scott and Work were intrigued, so they signed on and set about testing turtle shells, much the same way they might test a sample of steel or concrete. It wasn't easy — the shells are not the same thickness throughout and they have a natural curvature that makes them difficult to test.

Using the results of these tests, the team built a large number of artificial turtle shells using fiber reinforced polymers. They affixed the shells to artificial turtle bodies, added instruments and sensors, and zoomed over the test specimens with a variety of boats to get a sense of the damage such impacts would cause. They used that data to build a better "shell" with polyurethane foam and a specialized polyester resin and ran another series of tests in the water.

"We found that the engine type and the speed at which you hit [the turtle] are primary factors for determining the lethality of vessel strikes; the depth of the turtle and the hull shape don't have a significant impact," Scott said. "If a turtle gets hit by a propeller at speed, whether it's at the surface or deeper in the water, it is likely going to have a catastrophic injury."

Turtles struck by jet-driven watercraft or just the hull of a boat are likely to avoid serious injury and survive, Scott said, which is valuable information for state officials considering whether new restrictions on boaters make sense.

"If you had areas where you were very concerned about catastrophic injuries on turtles — for example, in breeding areas — you may not need to completely restrict boats from those areas, but you could restrict boats with propellers from traveling at speed in those areas," he said.

Scott said the DNR took the team's advice, weighed it against the impact of new regulations, and restricted propeller-driven craft in some areas where the turtles liked to nest.

"We didn't provide the final answer to their questions, but we certainly provided them with data that they could use to make decisions," Scott said.

"What makes this unique was that we weren't trying to build a better turtle, and we weren't trying to take the concepts of what makes a turtle shell work very well and apply them to civil infrastructure," he said. "We were trying to understand, when turtles come into contact with man, is it always a catastrophic occurrence? And are there ways that we could limit those interactions that would benefit the turtle, while still allowing folks to do the kinds of things that they like to do and still have access to these regions?"

"It was a really unique chance for me to take things that I had been using for a long time as a structural engineer and apply them in a way that I had not previously considered." ▪

M IS FOR MACHINE LEARNING

And CoE is using it to invent the future!

1959 The year engineer and innovator Arthur Samuel coined the term

'Machine Learning' means:

Engineering ways for computers to learn without being programmed. ML is a key tool for Artificial Intelligence.

ML@GT is Georgia Tech's **interdisciplinary research center** for machine learning (CoE + 5 other GT colleges)

150/400 Number of **faculty/students** involved in the ML@GT center

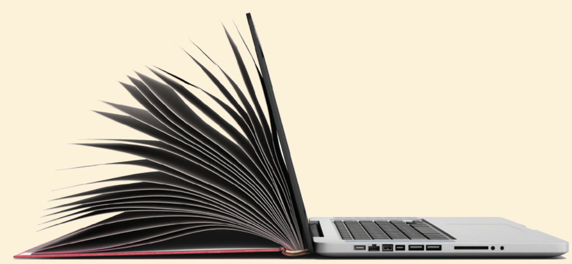
Some real-life machine learning projects from CoE faculty

Auto-generated highlight reel

Crowd noise or player motions at a basketball game trigger the capture of audio/video clips of stellar plays

Healthier Georgians

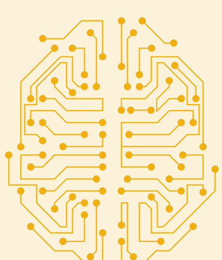
Computer-generated insight from data guides health policy and practice decisions in communities across the state



Reading a closed book Software converts "echoes" – collected from a high-frequency pulse shot at a stack of pages – into understandable content

A real expert – or not?

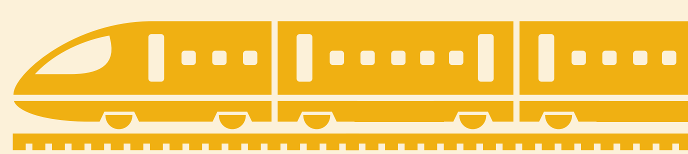
A person's skills are assessed by a computer based on the machine's comparison of that person to video footage of a real expert



Brain-powered action Surgically implanted chip allows a person with paralysis to control a computer purely by thought

Predicting equipment failure

Sensor-generated data from gas turbines, locomotives and other high-stakes machinery is continuously captured and analyzed so that catastrophe is averted



N is for **NUCLEAR SECURITY**

New designs to enhance nuclear security big step in bringing clean energy to households

by Georgia Parmelee

Nuclear energy is reliable, renewable and clean, emitting zero carbon into the atmosphere. Just one penny-sized pellet of uranium fuel used in nuclear power generation contains as much energy as 150 gallons of oil. But nuclear energy can be catastrophically dangerous if it's used incorrectly or weaponized. The National Academy of Engineers has identified preventing nuclear terror as one of the 14 grand challenges for engineering in the 21st century. While nuclear energy can be extremely beneficial for our planet and the economy, nuclear security is tantamount to ensuring public safety.

Anna Erickson, assistant professor at the George W. Woodruff School of Mechanical Engineering, Nuclear and Radiological Engineering department, works at Georgia Tech to create new approaches to nuclear security. One involves radiation detection devices and the other is focused on nonproliferation of nuclear materials in nuclear power.

Radiation detection devices are used to measure the amount of radiation in the environment and are very important for border security as shipping containers enter the U.S. Erickson has been developing technology for scanning cargo containers by using an external source of radiation, similar to baggage scanners at airports, but on a much larger scale. The new technology relies on low-energy nuclear reactions instead of traditional x-ray sources to minimize cargo exposure to harmful radiation. Erickson's scanning technologies also include equipping a drone with a radiation detection device, which has automated search capabilities. Not only does this speed up the process of screening containers or facilities of interests, but it also keeps humans out of harm's way. This mobile detector could have the potential to work in crowds to ensure there are no radiation threats at large public gatherings.

The other focus for Erickson is on nonproliferation-by-design, meaning creating nuclear energy that isn't leaving massive amounts of plutonium behind. The field of nonproliferation is aimed at deterring people from even thinking about creating nuclear weapons by limiting the amount or quality of nuclear material that is produced.

To drive the goal of nonproliferation forward, Erickson and her team have been involved in an antineutrino monitor design — a device that detects tiny antineutrino particles in the atmosphere. Nuclear power plants emit large amounts of antineutrino particles as nuclear energy is generated. Erickson's group is exploiting the advances in antineutrino detector capabilities to yield a continuous, unobtrusive and unfalsifiable way of obtaining information on a nuclear core, including production of plutonium. The Plutonium Management and Disposition Agreement between Russia and the U.S. has mandated that plutonium must be responsibly disposed of in nuclear reactors, so there is less chance of weaponization. Erickson's antineutrino monitoring device would be helpful for observing fuel evolution in the reactor to ensure the disposal was complete. Placed outside of a nuclear plant, antineutrino monitors can also be helpful in continuous reactor monitoring, reducing disruptive inspections inside the plants.

"You only need eight kilograms of plutonium to make a weapon, and countries are keeping about 500 metric tons of separated plutonium on hand," said Erickson. "With the antineutrino monitoring device, we can know whether or not to trust other countries when they tell us they are disposing of the plutonium properly."

Nuclear security must be monitored carefully, step by step, to ensure safety. But if it's done correctly, then a very efficient and environmentally sound energy is at our disposal, which could make all the difference in the years to come. ▪

O is for ORIGAMI ENGINEERING

Paper folding helps civil engineers with research

by Joshua Stewart, Liz Ahlberg and John Toon

The ancient art of paper folding has begun to unlock all kinds of new possibilities for engineers, and Glaucio Paulino in the School of Civil and Environmental Engineering is one of the visionaries leading the way.

Paulino and his colleagues study origami patterns to find new ways to apply them to modern engineering challenges. They've developed new kinds of reconfigurable and deployable structures that occupy almost no space when folded up but expand dramatically — and present a variety of applications, from robotics to sustainable buildings to healthcare.

"All of these ideas apply from the nanoscale and microscale up to large scales and even structures that NASA would deploy into space," said Paulino, the Raymond Allen Jones Chair in civil and environmental engineering. "Depending on your interest, the applications are endless. We have just scratched the surface. Once you have a powerful concept, you can explore applications in many different areas."

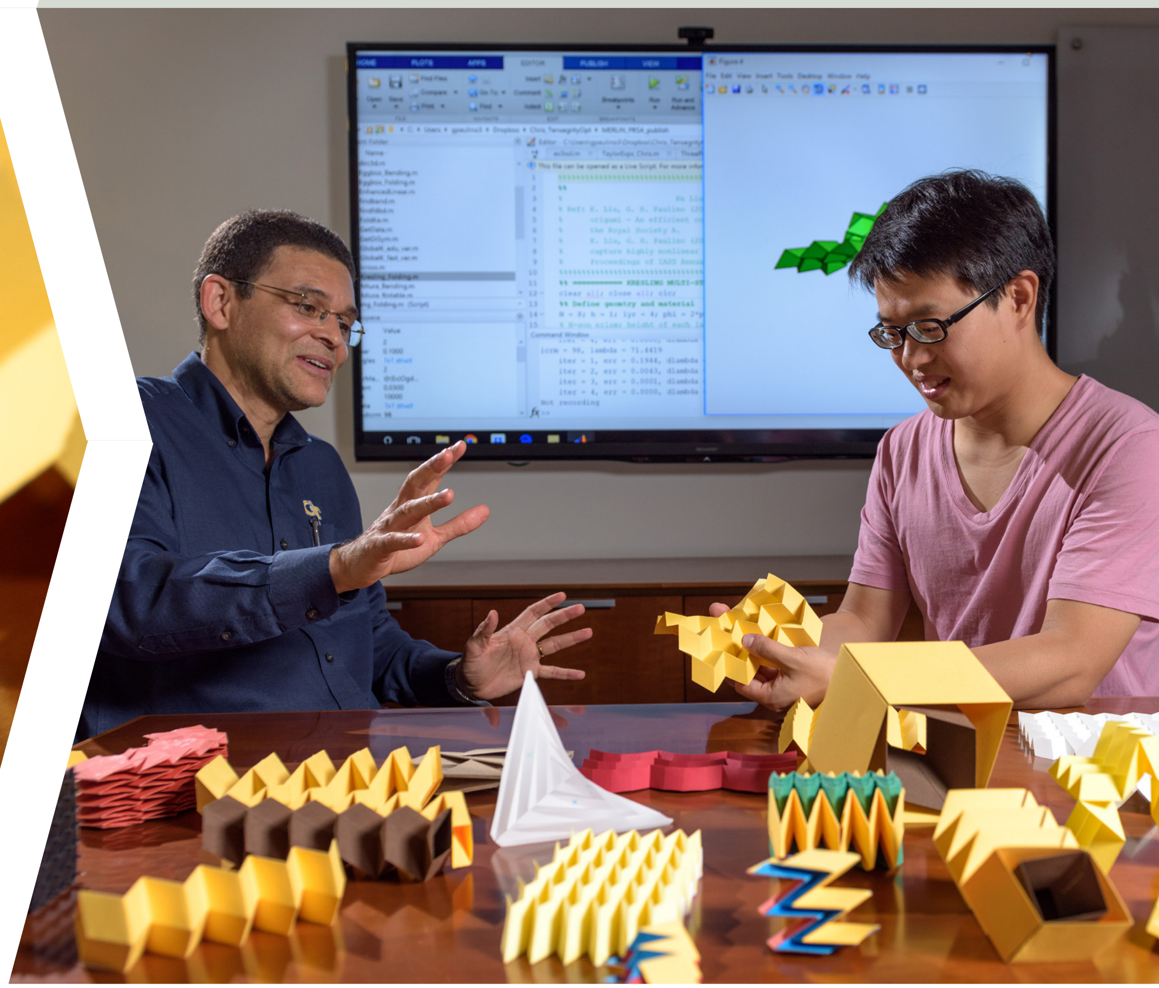
Paulino, along with one of his students and a colleague in Japan, has been on a tear over the last 18 months, publishing several of these powerful concepts in leading scientific journals.

One, the "zippered tube," coupled two paper tubes of origami into a configuration that could hold significant weight but fold flat for shipping or storage. Using plastic, metal or other thin

materials, their technique could be used to make bridges that deploy quickly after a disaster or even temporary shelters.

The team created another kind of origami tube that can be configured in multiple ways and have different properties as a result. At the engineering and architectural scale, tubes could serve as ductwork, piping or even structures to provide shade for buildings during hot parts of the year. Smaller tubes could carry electromagnetic energy and function as antennas, with different folds allowing them to operate at different frequencies.

“We have also developed a mathematical theory that goes along with it that allows us to design the tubes and predict how they can be reconfigured or reprogrammed,” Paulino said, so the researchers can make tubes with the exact properties electrical engineers, civil engineers or other users need for their applications. ▪



Above: Researchers Glaucio Paulino (left) and Ke Liu, School of Civil and Environmental Engineering, with origami structures that can be simulated in new software. Credit: Rob Felt

P

is for **PREDICTIVE HEALTHCARE**

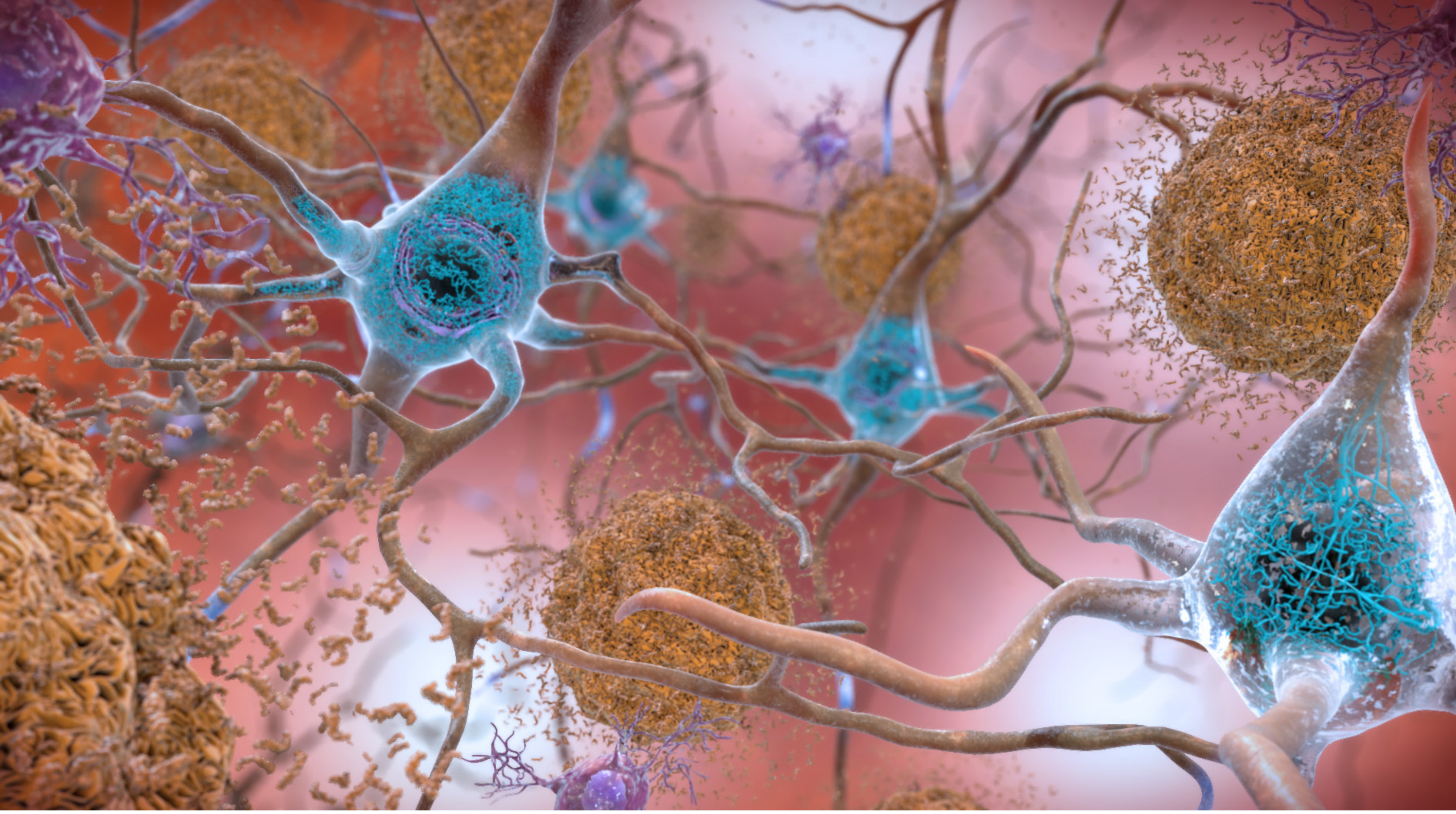
Big data helps doctors treat, cure and improve patient outcomes

by Georgia Parmelee

For Cassie Mitchell, predictive healthcare means using data analytics and computational approaches to best predict what care or treatment is going to work for a patient. Predictive healthcare is instrumental in identifying what Mitchell refers to as the three C's: cause of a disease, cure simulation, and care optimization for patients.

"Predictive healthcare is just an extra, objective tool that can help the physician and patient make better decisions," said Mitchell, assistant professor in biomedical engineering at Georgia Tech. "The analytics assist by calculating odds of diagnostic and treatment success. By 'picking winners' among thousands of possibilities, predictive healthcare expedites biomedical research and clinical trials, so patients get the care or cure they need, sooner."

Mitchell's lab is best known for taking disparate data and stitching it together "into a quilt," she says, to identify disease patterns. Having access to millions of different measurements and data points allows her to conduct research on multifactorial diseases, or conditions caused by many contributing factors, such as Alzheimer's Disease, Amyotrophic Lateral Sclerosis (ALS) and some cancers. Rather than isolating one



factor of a disease, Mitchell's predictive healthcare work holistically examines disease factors to predict an effective course of treatment.

Mitchell's lab is working on a few predictive healthcare projects right now.

ALZHEIMER'S

Researchers do not know the exact cause of Alzheimer's, though, they suspect it has to do with amyloid beta plaque buildup. Mitchell's lab analyzed data integrated from the entire Alzheimer's field and found that the correlation between cognition and beta plaque to be very weak. In reality, the cognitive dysfunction seen in Alzheimer's patients is more closely related to overproduction of phosphorylated tau (p-tau), a protein that makes up the backbones of neurons. Mitchell's data-driven research suggests that p-tau may be a better treatment target than the classic amyloid beta plaques that have been the primary focus of researchers for decades.

ALS

Mitchell also works on ALS, a rare neurological disease. Most ALS patients will eventually experience difficulty breathing, requiring a Bi-PAP (bi-level positive air pressure) to help the breathing muscles to do their job. The Bi-PAP is only used (and covered by insurance) when the ALS patient's breathing capacity falls below 50 percent of normal. But Mitchell and others recognize that a patient has already succumbed to the disease at that point. There are a variety of characteristics that indicate an ALS patient is ready for Bi-PAP, and Mitchell's lab recently showed that survival rates double if patients are put on a Bi-PAP sooner. Applying predictive healthcare to the insurance world allows patients earlier access to key interventions like Bi-PAP, and they can make better decisions about their care.

LEUKEMIA

Depending on a patient's unique disease characteristics, medical history and lifestyle, doctors can use predictive healthcare models to create a personalized medicine plan that is tailored to the patient. Cancer was one of the first fields to use personalized medicine to customize chemotherapy based on genetic-mutation profiling to maximize cancer cell killing power. However, killing cancer cells is only part of the equation. Most treatments have negative side effects, and many patients, such as those with chronic myeloid leukemia, are currently given the recommendation to stay on treatment for life.

With patients now living much longer, predicting the long-term toxicity and side effects of chemotherapy drugs is important. Mitchell is developing clinical-decision models to better predict side-effect profiles years in advance. The information can also be used to better customize a patient's treatment options at diagnosis, during progression, or even during remission, making predictive medicine an important tool for enhancing patients' overall quality of life. ▪

Above: Artist's rendering of amyloid-beta plaque (beige clumps) outside of neurons and neurofibrillary tangles (blue) inside of neurons. Credit: National Institute on Aging, National Institutes of Health

Opposite page: Cassie Mitchell's lab. Credit: Rob Felt

is for **QUANTUM DOTS**

A dot too small to see, a revolution in color and light

by Desirina Frew

Most solar panels are made from silicon. They're heavy and bulky, and installing them on a roof is a job for a team.

But imagine a solar panel as light and flexible as a sheet of paper. You could roll it up like a poster and take it anywhere. You could put it in a window or on top of your car. You might even be able to wear it, efficiently generating your own power source wherever you go.

Researchers like Zhiqun Lin are working to create such an energy source by using a nanotech innovation called "quantum dots" that would reside on a light, flexible sheet. One obstacle is the instability of quantum dots, but Lin, a professor of materials science and engineering at Georgia Tech, may have found a way to conquer this challenge.

Quantum dots are human-engineered semiconductor particles, just two to 10 nanometers in diameter (that's about 10 to 50 atoms). They're made by using heat or a catalyst to induce a chemical reaction in metal to form tiny nanocrystals.

What's fascinating about quantum dots is that their color is intrinsically linked to their size. Larger quantum dots are red. Smaller quantum dots are blue. In the middle are orange and green.

A single quantum dot is far too small to see, but in the billions they emit crisp, clear, vibrant color. They're already the hottest new thing in high-definition television and monitor screens. They could also be used to make much more efficient solar cells because they absorb more sunlight by scooping up rays at every single point on the spectrum.

But their instability is a drawback.

Much like a grain of salt, quantum dots are fragile. Plus, they disintegrate quickly when exposed to air and moisture. Not ideal for a solar panel that lives outside, exposed to the elements.

Lin and his team are modifying the dots to make them more stable. First, they applied a top coat to make them water repellent. Second, they encased each quantum dot in a shield made of an inorganic material, and then added the same water-repellent materials on top of the shield.

Testing is still under way, but Lin is confident the results will be even more significant. Combined with the encapsulation techniques already in use for quantum dot LCD screens, which protect components in layers of glass, these quantum dots could be sturdy enough to create the solar panel of the future. ▪

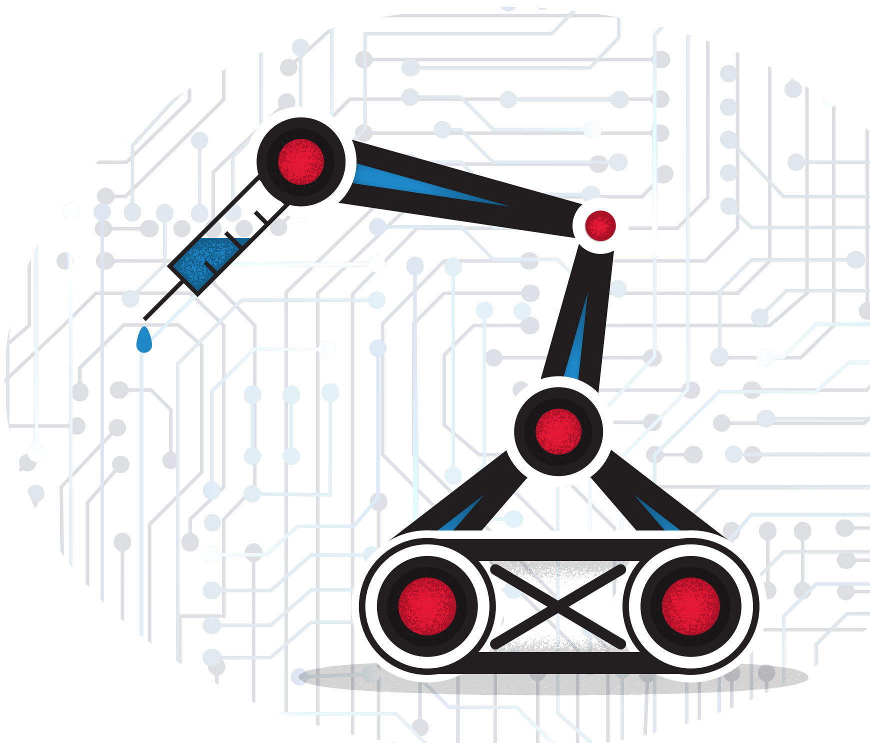
What's fascinating about quantum dots is that their color is intrinsically linked to their size. Larger quantum dots are red. Smaller quantum dots are blue. In the middle are orange and green.

R is for **ROBOMED**

Robots scrub in on surgeries

by Polly Ouellette

Peer into an operating room, and you'll see a crowd of people — scrub nurses, anesthesiologists, interns, surgeons, and now, robots. These electronic helpers assist during surgeries by providing doctors with additional precision, delicacy and dexterity.



QUENTIN LUENINGHOENER

Today in the RoboMed Lab, Jaydev Desai, Georgia Tech biomedical engineer and associate director of Medical Robotics & Human Augmentation, is designing tiny robots that can maneuver within veins or brain tissue. He's focused on creating revolutionary and cost-effective robotics to be used in surgery, diagnosis and rehabilitation.

Many of the projects underway in the RoboMed Lab are concerned with delicate brain surgery. A deep intracranial tumor removal robot and an intracerebral hemorrhage evacuation robot are both intended to remove objects, like a cancerous mass or an excess amount of blood, from the brain.

Veins and arteries can benefit from robotic-assisted surgeries as well. The team is developing an extremely tiny robot that will help surgeons navigate a patient's blood vessels for arterial blockage removal. RoboMed Lab researchers are also improving prosthetics and exoskeleton devices for the hands and fingers. They want to help patients restore their fine motor skills through the study of joint movement.

These advancements have the potential to change lives, but they can come at a very high price point for patients. One of Desai's biggest goals is to ensure that the devices his lab produces are socially equitable. For example, he wants robot-assisted rehabilitation to be something that a patient can perform at home, instead of paying for an in-clinic procedure.

"We would ideally like the robots to be low cost — affordable for somebody who is economically disadvantaged and cannot afford to go to the clinic twice a week or lives in rural Georgia," said Desai.

Creating low cost materials that can still perform the proper tasks adds to the challenge. Desai and his team focus on finding low-cost manufacturing techniques to build their robots. For example, 3-D printing cuts the cost of a neurosurgery robot from $900,000 to under $10,000.

Once the robotic devices pass numerous tests and inspections and make it into hospitals, they will perform tasks with speed and accuracy far greater than that of a surgeon. Robots don't suffer from fatigue during a long surgery, and they can repeat a task in exactly the same way, as many times as is required. But Desai says surgeons shouldn't fear for their jobs.

"I am a big proponent of the use of robots under the guidance of a clinician — it's never a fully automated procedure," said Desai. "Almost every time a surgeon performs a procedure, they come across something they have not seen before, and they have to make a decision on the fly. Surgeons can make the right judgment call because of years of practice, and it's going to be very hard for robots to catch up."

Still, the work of RoboMed Lab has the potential to change the future of medicine. Robots can perform neurosurgery with greater accuracy and fewer complications. In the coming years, expect to see more robotic systems scrubbing in on surgeries. ▪

S is for SHENZHEN

Tech lands in China's Silicon Valley

by Georgia Parmelee

ESTABLISHED IN **1980**

POPULATION **18M**

AVG. AGE **30**

- Highest GDP per capita among large & medium Chinese cities
- The Port of Shenzhen is the 3rd largest container port in the world

Since Shenzhen became a city 40 years ago, education options are limited. So, the city is looking to schools like Georgia Tech as partners that will benefit the university ecosystem. A few years ago, Tech's College of Engineering accepted 400 acres of land from Shenzhen to start an engineering master's program for the School of Electrical and Computer Engineering.

Shenzhen is commonly referred to as the Silicon Valley of China. It's a bustling metropolis, serving as a high-tech innovation hub in the Asia-Pacific region. It's a forward-looking city with a modern transportation system and has a special economic zone designation, offering tax and business incentives to attract foreign investment and technology. In fact, both Apple and Google have recently opened research and development centers in Shenzhen.

Students are attracted to the Shenzhen program for the international exposure. China is a major world economic player and having experience in the country opens doors for career opportunities. The program also offers free Chinese language courses, and it facilitates internship placement for all students. The next step for Tech is to offer programs in environmental engineering, analytics, computer science and industrial design. As the program grows to include a variety of engineering degrees, more Tech students will enjoy access to the clean, green city that boasts a young population with high-tech interests. ▪

T is for TRAFFIC

Autonomous cars are coming, but not just yet

by Georgia Parmelee

Atlanta has some of the worst traffic in the world — 10th worst, to be precise, if you believe the 2017 INRIX global traffic scorecard. Building more highways and adding more lanes is no longer a long-term solution to improve traffic; technology offers cities another approach for congestion relief.

Researchers at Georgia Tech, located adjacent to Atlanta's notoriously clogged highways, are working to solve those traffic problems, while considering the possibilities — and perils — of new technologies coming online in the near future.

"In order to improve and control traffic, we have to get the model right," said Sam Coogan, an assistant professor in the College of Engineering. "Traffic is very complex, so it is critical to understand how it behaves. You can't just put down more pavement to get improved performance and efficiency. You have to leverage technology."

Coogan is working to build new mathematical models of traffic flow based on an ever-increasing pool of real-time data from cars, roads and other infrastructure. Coogan says these models will allow him to study how densities of traffic change over time, without having to simulate the traffic problems. The Georgia Department of Transportation (GDOT) relies on these models and recommendations for traffic calming in the city.

An important question is how those models will operate in traffic flow changes when autonomous vehicles begin regularly traveling our roads. More and more states are allowing semi- or fully autonomous cars on their roads, and in theory, they should improve traffic. For example, a highway might be able to handle 2,000 regular cars per hour in each lane. If the cars are autonomous and platooning (vehicles grouped together to increase the capacity of roads), that number triples to 6,000. However, Coogan says autonomous vehicles remain a long way off.

"We are starting to see semi-autonomous cars on the roads, like adaptive cruise control and lane-keeping technologies," Coogan said. "Before fully autonomous cars hit the roads, we will probably see a vehicle that you manually drive to the highway, move to a designated lane, and then press a button for an autonomous ride."

In addition to efficiency, Coogan sees autonomous cars and smart city grids as opportunities to create equity in our communities. Transportation will be able to reach underserved communities or offer the ill and elderly access to cars. Ride sharing will also enable equity by providing less expensive alternatives to driving.

But autonomous vehicles are not going to improve traffic overnight, Coogan said. One of the greatest challenges for transportation today is how to make the most of the infrastructure already in place, and it's going to take proactive effort. Once our transportation system becomes electrified for autonomous vehicles, it will change everything — from routes with charging stations to how to pay for fuel. It will create a whole new automotive economy. ▪

U is for **UNMANNED VEHICLES**

Finding the way to faster, safer, self-piloted transport

by Desirina Frew

What's the best path from point A to point B? You might say it's the one that's safest. Or easiest. Or fastest.

But the best path is a reasonable compromise of all three. And finding that compromise can be complicated.

Your brain makes calculations all the time. The best way to get to work during rush hour. The quickest route from the couch to the fridge. (Avoid the loose Legos, maybe risk stepping on the dog.) You don't really contemplate these minor corrections in navigation — they just happen.

Unmanned vehicles (UVs), whether aerial vehicles like drones or ground vehicles like self-driving cars, face similar challenges. Which is why researchers like Evangelos Theodorou, assistant professor at Georgia Tech's School of Aerospace Engineering, want to build UVs with the autonomy and agility to make complex decisions under split-second pressure.

Engineers think about autonomy as a three-step process: plan, sense, execute. You make a plan. You sense the environment to see if your plan will work. If yes: execute said plan. (If no, well, plan some more.)

Autonomy means continually cycling through those three basic steps. But Theodorou approaches the problem differently. To inform the development of pilotless vehicles, he studies across disciplines and draws on techniques from three fields — control theory, statistical physics and machine learning. Each has its own perspective on finding the best route between point A and point B.

PHOTO COURTESY: THEODOROU LAB

Experts in each field have their own way of talking about the problem and solving it. But Theodorou realized they were all tackling the same challenge. He used insights from each field to develop a set of algorithms unlike any before.

Under this new paradigm, an unmanned vehicle doesn't need to plan, sense and execute in succession. It can use parallel computation to make the calculations simultaneously — more like the human brain. Instead of solving the problem one step at a time, it can break it into smaller problems and devote processing power to each.

"These algorithms are able to predict what will happen in the future, what happens down the road, by creating thousands of possibilities," Theodorou said.

The result is unmanned vehicles that are more agile, adaptive and quicker to react to obstacles, which makes them faster and a lot safer.

Theodorou's lab was awarded a National Science Foundation I-Corps grant, which advances American innovation by bridging the gap between research lab and commercial product. His team has developed a business model and is meeting with dozens of interested companies around the country.

Thanks to Theodorou's work, the path to self-piloted transport just got a little easier … and a little shorter. ▪

V is for VINEGAR

All-natural herbicide grows green grass

by Joshua Stewart

Grace Brosofsky's research into natural herbicides started at home. Brosofsky's mom didn't want to use any harmful chemicals on their north Georgia lawn to control weeds, but her dad couldn't stand the way the yard looked. An aspiring environmental engineer, young Brosofsky saw a chance to solve their disagreement at an upcoming science fair. For her project, she tested different natural herbicide mixtures on the family's lawn to find an effective organic weed killer.

Brosofsky's interest in environmentally friendly solutions continued at Georgia Tech, where she connected with the student chapter of Engineers for a Sustainable World to continue her work. She even persuaded Tech's landscapers to let her run a few tests on campus.

After testing and analysis, Brosofsky's team came up with a mixture of concentrated acetic acid and d-Limonene: vinegar and citrus fruit oil — a natural herbicide. They won a President's Undergraduate Research Award to hone in on the right mix and run a larger, more scientific campus-wide study.

"We found that 20 percent, 40 percent and 60 percent concentrations of an acetic acid and d-Limonene solution performed better over time than the organic herbicides currently on the market, and that the 40 percent and 60 percent concentrations worked as well as the chemical herbicide RoundUp," said Brosofsky, who graduated in May 2017 and is now studying environmental law.

Simple, safe, and, she says, economical: "We determined that if we can buy acetic acid and d-Limonene in bulk, we can make and sell our solution for less than the market price of RoundUp."

The group's efforts included teaching low-income community gardeners in Atlanta how to make and use the natural herbicide and helping with their gardens. They taught Georgia Tech students to use it, too, on a student-tended campus garden.

Their work won national acclaim in the fall, when a campus sustainability organization recognized Brosofsky and her team. Now, chemical engineering student Ilinca Birlea and civil engineering major Emmeline Yearwood have taken over the project and turned their focus back to campus, working with Tech's sustainability committee on landscaping for the new Kendeda Building for Innovative Sustainable Design. ▪

Top: Grace Brosofsky, B.S. EnvE 2017, with her Student Sustainability Leadership award from the Association for the Advancement of Sustainability in Higher Education. Photo courtesy: Grace Brosofsky

Above: One of Brosofsky's experimental plots as part of a Google Science Fair project she developed. A mixture of vinegar and d-Limonene was applied to the section of weeds on the right. No treatment was used on the area to the left. Photo courtesy: Grace Brosofsky

W

Beyond entertainment enhancements, Chang hopes to harness 5G wireless technology to create a safer world. He's leading his team in the development of a lower latency 5G network, meaning faster internet and communication services that are even more reliable.

is for **WIRELESS 5G**

Your favorite streaming service, even faster

by Polly Ouellette

At the 2018 Winter Olympics in PyeongChang, South Korea, viewers watched 360-degree videos of the games from the comfort of their homes and received nearly instantaneous mobile updates on who took home a medal. Worldwide wireless networks are what made this possible.

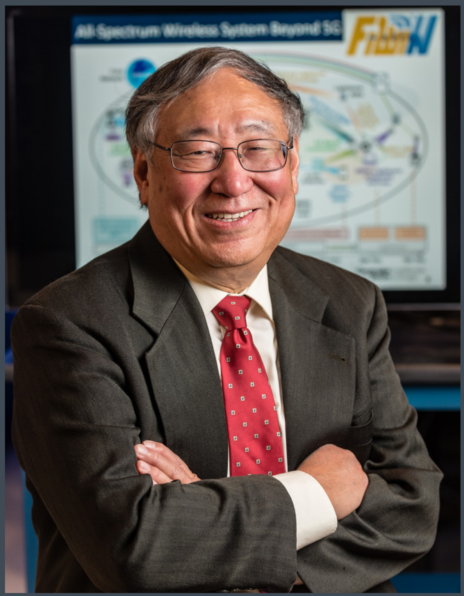
The 2020 Summer Olympics in Tokyo, Japan, will provide an international stage for even further advanced technology. The recent Winter Olympics were just a preliminary trial run for Intel, who just announced that it will be providing 5G wireless connectivity for the Tokyo games, as well as a simultaneous global rollout of the service.

Gee-Kung Chang, a professor in the School of Electrical and Computer Engineering, says that Fifth-Generation (5G) wireless technologies will be quicker in every way. They will transmit information through radio waves at a higher frequency, allowing downloads to happen 10 times faster. While the current generation, 4G, only allows downloads of up to one gigabit of information per second, 5G will permit downloads of up to 10 gigabits per second.

However, the expansion of infrastructure to create fast, high definition consumer entertainment won't be easy or cheap, and carriers must decide if the new generation of wireless is worth it. It also means fierce competition between wireless carriers and cable companies, who have already begun to feel challenged by streaming services like Netflix and Hulu. Testing of the new developments has already begun, and some areas in the U.S. will receive "wired" 5G later this year as streaming companies begin to roll it out.

Beyond entertainment enhancements, Chang hopes to harness 5G wireless technology to create a safer world. He's leading his team in the development of a lower latency 5G network, meaning faster internet and communication services that are even more reliable. In dangerous situations like natural disasters or fire, emergency messages can be transmitted with extra speed and help can arrive faster. In addition, low latency communication between autonomous vehicles will help to mitigate accidents and collisions.

Chang says that as communications companies expand their infrastructure, 5G will be able to reach more people and will be able to benefit rural areas, as well as urban and metro ones. This is where the impact of the new technology will be felt the greatest.



GARY MEEK

"Families in rural areas don't have the extra money for high speed internet," said Chang. "We want people who barely have a computer terminal to also receive 5G services to create equity."

With their research, Chang and his team hope to ensure that 5G customers receive both entertainment and safety, as quickly as possible. ▪

X is for

X-RAY TOMOGRAPHY

How an insanely powerful X-ray can help map the brain

by Desirina Frew

Using the 3-D X-rays, Dyer and her colleagues are imaging thicker samples of mouse brains that can show how brain architecture functions in three dimensions. Newsweek described the potential of Dyer's work as "Google Maps for the brain."

Consider, for a moment, the human brain.

It's the most complex organ known to humanity; it might just be the most complex structure in the universe. The human brain holds as many neurons as the Milky Way holds stars. Understanding the inner workings of this biological super-computer is one of science's greatest challenges — and there is still a lot we don't know.

Eva Dyer, an assistant professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory, is tackling this challenge. Combining super-powerful X-rays with advances in data science, Dyer is pioneering a new way to see the brain.

Dyer partners with researchers at Argonne National Laboratory, using the facility's synchrotron X-ray to produce three-dimensional images of the brain with astounding clarity. This 3-D image is similar to a CT scan, but so crisply detailed as to reveal individual neurons, blood vessels, axons and cells.

Before now, such precision could only be achieved by obtaining a hair-thin slice of brain matter, injecting a tracer stain, and taking a picture. Not only is that process complicated and taxing, it can only focus on one type of brain feature at a time, not the whole picture.

Using the 3-D X-rays, Dyer and her colleagues are imaging thicker samples of mouse brains that can show how brain architecture functions in three dimensions. Newsweek described the potential of Dyer's work as "Google Maps for the brain."

But creating this hyper-detailed image is just part of Dyer's focus. As a neuroscientist who's also trained as a computer scientist, Dyer is developing new ways to put this immensely detailed data to work.

Using techniques from data science and machine learning, Dyer and her team are developing algorithms to translate the 3-D X-rays into easy-to-scan visualizations — highlighting key features such as neurons and blood cells.

Neuroscientists could use this information to make new discoveries in comparative anatomy. By comparing brains in mice, primates and people, they could see how the brain's architecture varies across evolution, and gain insights into such questions as *How does the structure of a brain give rise to higher intelligence, and what exactly makes a person smarter than a mouse?*

Researchers could also use this data to understand hallmarks of neurodegenerative diseases such as Alzheimer's and Parkinson's, and how these conditions progress over time. And they could analyze the effects of concussions and traumatic brain injury.

"There have been incredible advances in imaging and data collection within neuroscience," says Dyer. "What we really need now is the ability to take these massive data sets and make sense of them. We need computational methods, such as machine learning, to facilitate discovery."

Dyer's work is meeting that need, producing both Big Data and robust data-analysis tools — the building blocks needed to better understand the brain and support the next decade's biggest discoveries. ▪

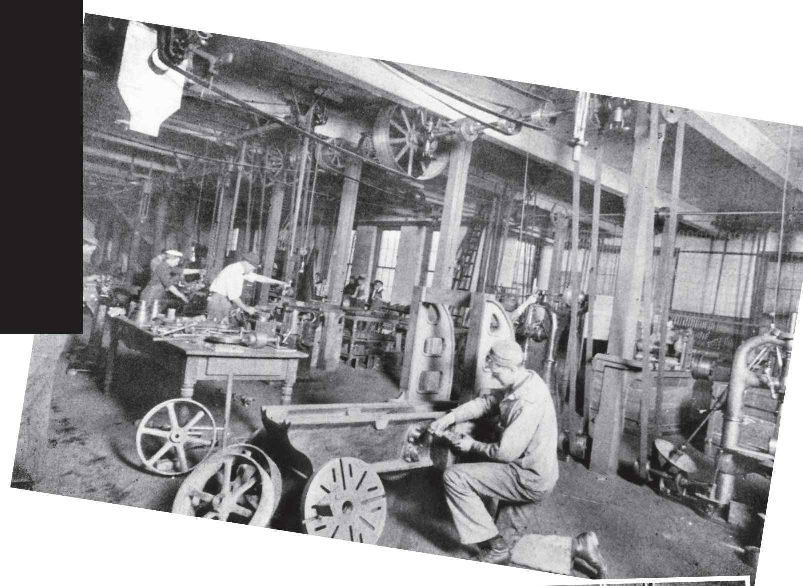
Opposite page: Assistant Professor Eva Dyer works with a detailed X-ray image. Credit: Rob Felt

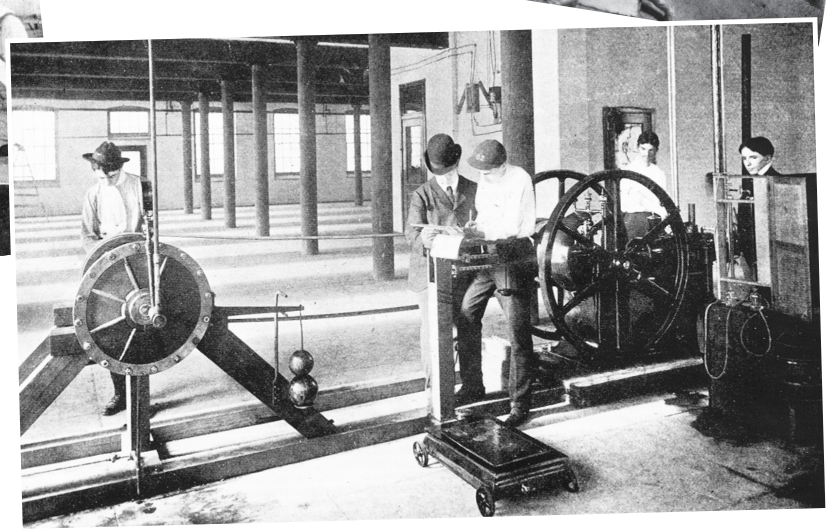
Y is for YESTERYEAR

Georgia Tech 130 years later

by Candler Hobbs

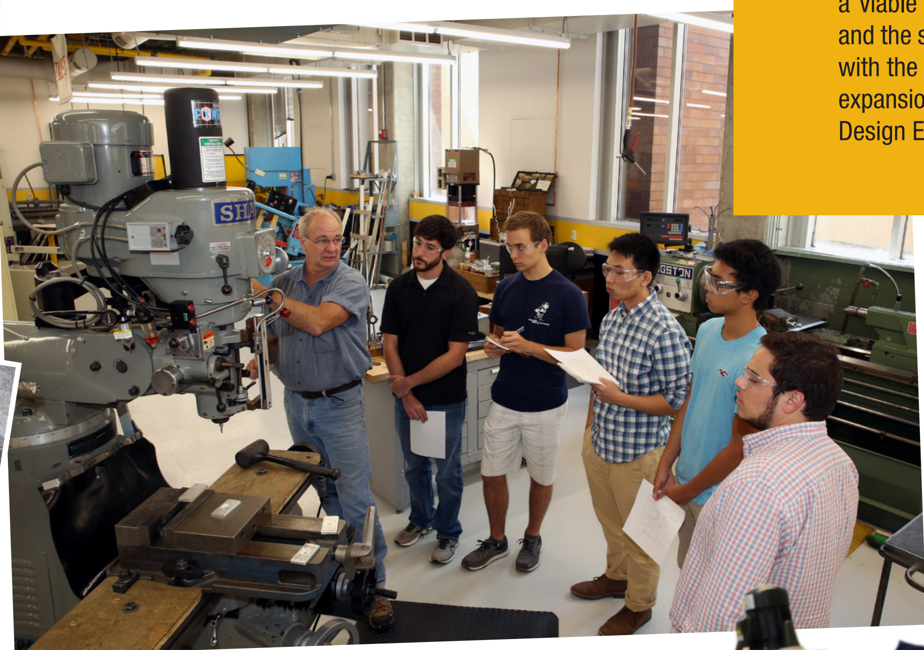
In October of 1888, Georgia Tech opened its doors to 84 students. At the time, mechanical engineering was the only degree program offered — an effort to supply qualified technical personnel to a region that greatly needed economic growth after the Civil War. When Georgia Tech began, the campus consisted of two similar towers, one housing classrooms and the other shops, indicating that nearly equal weight was to be given to "practical" education, as well as academic course work.





Clockwise from top: Georgia Tech's first two buildings, the shop building (left) and the academic building (right) opened in 1888; the machine shop (1908); testing a gas engine for horsepower (1904); & the wood shop (1897).

Much has changed over the last 130 years, but several key aspects have always remained the same. A hands-on learning experience is still a viable part of the Georgia Tech mechanical engineering curriculum and the shop-culture at Tech is still alive and well — thriving, in fact — with the new addition of the Montgomery Machining Mall, the constant expansion of the Invention Studio, and the growth of the Capstone Design Expo over recent years. ▪



Clockwise from top left: research (2017); Montgomery Machining Mall (2016); IDEA Lab (2018); Invention Studio (2016); Montgomery Machining Mall (2016).
Photo credit this page: Candler Hobbs.

is for ZINN COMBUSTION LAB

Seven things to know about the Zinn Lab and its namesake founder

by Michael Baxter

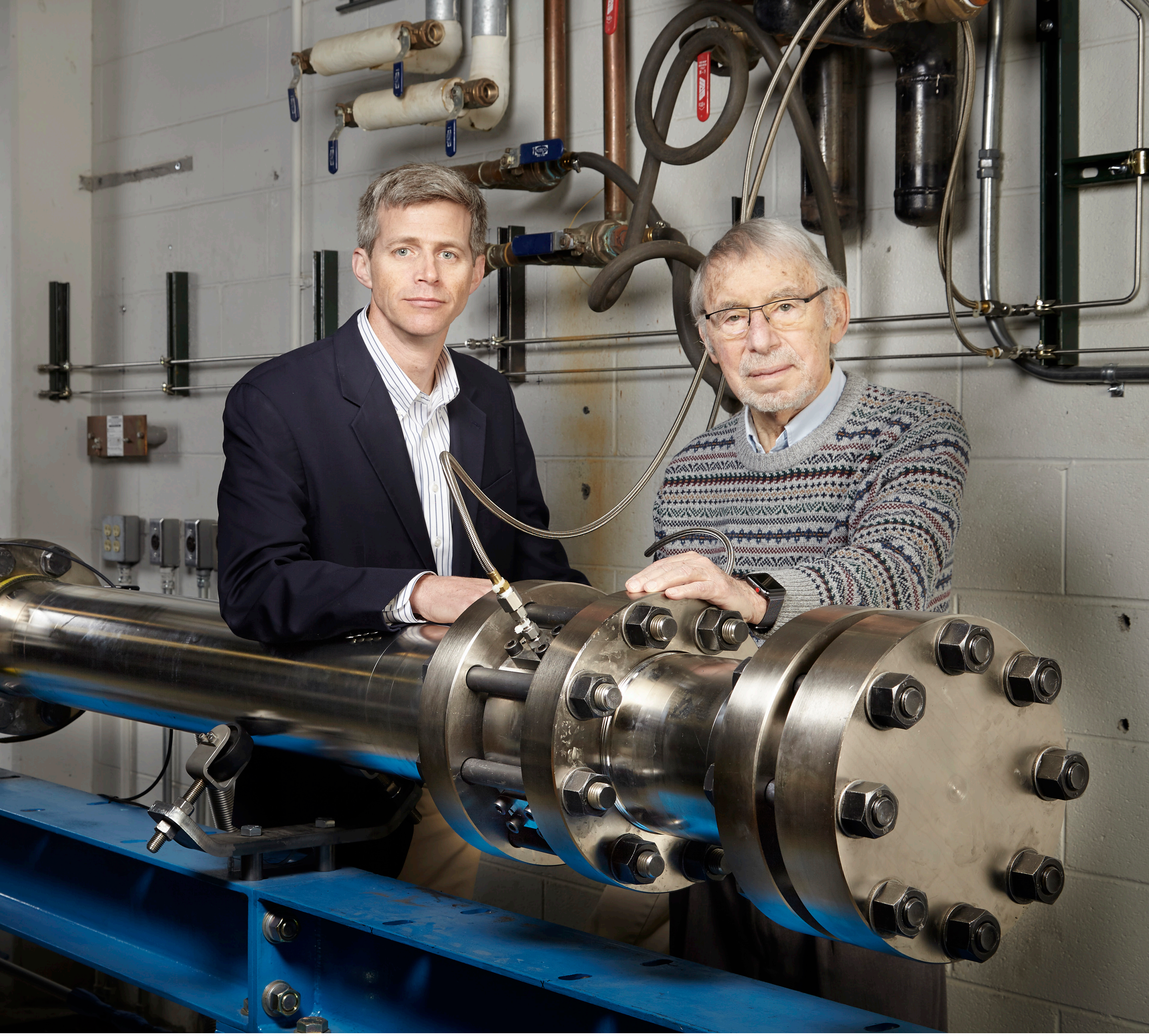
1. It started out in a shack. A “metal shack” attached to the Weber Building, to be exact. The year was 1965, and it was summer, “it felt like it was 500 degrees in there,” Ben Zinn recalls.

2. Today, the lab is really big. Not just in size — 18,000 square feet — but in stature and breadth of work. Nearly two dozen engineers and scientists conduct research there, aided by more than 50 graduate and undergraduate students. Today, it’s the largest university combustion research program in the U.S.

3. The current lab director started out as Zinn’s student. Tim Lieuwen recalls that his former professor was demanding and exacting: “There was this one paper — we must have revised it 50 times. I didn’t like it at the time, but it did end up being a good paper.” Ben Zinn remembers his former student as driven and diligent. “He kept emailing me about working in the lab until I finally said to myself, ‘This guy is so persistent, I’ve got to give him a chance.’ It was one of the best decisions I ever made.”

4. The lab is known for pragmatic and pioneering work. Methods and data used by industry to predict stability in combustion systems were developed by Zinn himself nearly a half-century ago. Zinn Lab scientists have broken new ground in the exploration of power generation and alternative fuels. They’ve also developed ultra-clean energy and propulsion technologies.

5. It’s also known for its strong ties to industry. Half of the lab’s research funding comes from the private sector, which is unique for an academic enterprise. Several major corporations — Pratt and Whitney, Siemens and Mitsubishi — have established Centers of Excellence inside the lab. “It’s extremely unusual that two major competitors in jet engine manufacturing would put their centers in the same place,” Zinn says.



CRAIG BROMLEY

6. It has the largest shock tube in the U.S. (outside of the military). Shock tubes are used to study the rate of chemical reactions in combustion. The unique size of the Zinn Lab shock tube allows researchers to simulate kinetics inside a rocket engine by generating very high pressure and temperature environments in a split second. “It took several years to build,” Zinn says, crediting the efforts of Wenting Sun, a celebrated combustion scientist recruited from Princeton.

7. Ben Zinn has ties to fame outside combustion research. He was a soccer star in his youth, playing for the Israeli and American national teams; as a hard-working student at Stanford, he passed on an opportunity to play in the World Cup. ▪

Ben Zinn is Regents Professor and David S. Lewis, Jr. Chair in aerospace engineering (emeritus) and the founder of the Zinn Combustion Lab. Tim Lieuwen is the current David S. Lewis, Jr. Chair in aerospace engineering, the director of the Strategic Energy Institute and the director of the Zinn Combustion Lab.

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