we are engineers

SPRING 2020

▶ GEORGIA TECH COLLEGE OF ENGINEERING

▶ HYPERSONICS — *MACH* SPEED AHEAD

▶ THE FUTURE OF MATERIALS

▶ THE AGE OF SPACE EXPLORATION

SPECIAL FEATURE ENGINEERING SOLUTIONS FOR COVID-19

THE ROARING TWENTIES

PROGRESS & SERVICE DEFINE OUR NEW DECADE

Friends of the College,

When we started working on this issue, the theme of the "Roaring Twenties" seemed appropriate given the vast research at Georgia Tech that has the potential to change the coming decade. But two months into the year 2020, the world began to deal with COVID-19, and everything changed. As I write this today, there are many unknowns and uncertainties in how our campus and work will respond, adapt and evolve in the next few years. What we do know is that we, along with many other institutions of higher education, roared into action on many fronts outside of research and education, from providing personal protective equipment and ramped up efforts for testing to developing potential vaccines and their delivery.

I have been amazed at the work being done by our faculty and students to support COVID-19 efforts, as well as the resiliency of our community to continue the research you will read about in this issue. Research is a fundamental piece of what we are about at Tech, whether it be in healthcare, in outer space, or in the quality of our communities. Out of this research comes new products, processes and inventions that will impact our lives for the better.

While COVID-19 put a halt to many activities on the campus, we continue to go forward into this new decade with a great deal of optimism and hope. As one crisis moved to the forefront, there are still many other issues that need the attention of engineers whose problem-solving skills are critically important in the years ahead.

Right now, two words seem to keep running through my mind — progress and service — and the vision and wisdom to help guide our actions. A vision for the College and its work moving forward. We need to see that which will change and what can change — whether it be in our classes or our research portfolio. And we need wisdom to help guide us through what lies ahead so that we can meet the challenges of the new decade and beyond, as well as help lay a path for a better tomorrow.

As always, we could not be as strong or as good as we are without your support, and for this, I am grateful.

Steve McLaughlin
DEAN & SOUTHERN COMPANY CHAIR
COLLEGE OF ENGINEERING
@gtengineerdean on Twitter

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Kit parts (green) and respirator parts (white) are being 3D-printed by MSE alum Kolby Hanley.

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WE ARE ENGINEERS
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Dear Readers,

Welcome to the Roaring 20s — Our New Decade. In this issue, you will read about the phenomenal research happening across the College that is reshaping our future, from medicine to sustainability. Our engineers are working on the front lines of space exploration, hypersonic technology and leading-edge materials, which will change the world as we know it. Within these pages you'll also read about the development of household robots and advances in AI. And, these are just a few areas where we excel.

A lot has changed since we went to work on this issue of the magazine. The issue, at its heart, is about the advancement of technology into the new decade. And the story about our COVID-19 heroes from across the College exemplifies what it means to push the bounds of research for the future. Our best and brightest engineers are working together to deliver face shields to healthcare workers. They are manufacturing ventilators and intubation boxes. We even have an alum who has turned his company's warehouse into a 3D printing factory for respirator parts. These are your fellow engineers who have stepped up to meet extraordinary healthcare needs.

Today, our students and researchers continue to do great work at Tech, even as the pandemic affects our daily lives. I hope you enjoy these stories that showcase some of their work.

Stay safe and happy reading.

Georgia Parmelee
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The story about our COVID-19 heroes from across the College exemplifies what it means to push the bounds of research for the future.

The Formula of Creativity

Robotics Ph.D. students Lakshmi Nair and Joanne Truong use creative problem-solving research to inform robotics that could potentially help in household tasks

In 1970, an accident on the Apollo 13 mission to the moon caused an explosion that destroyed an oxygen tank and threatened the astronauts' ability to return to Earth. The astronauts were able to use their ingenuity and the resources available on the command module to create a makeshift solution that provided them with enough clean air and power to make it home.

The famous Apollo 13 mission is an example of creatively solving a problem using only the resources available. This concept is often called "MacGyvering" — from a TV series in the 1980s — and is one of the primary inspirations for the work of engineer Lakshmi Nair, who is pursuing her Ph.D. in Robotics in the School of Electrical and Computer Engineering here at Tech.

Nair's research focuses on creative problem solving, and in particular, she is interested in developing algorithms that will allow robots to use the objects around them to complete a certain task.

"The Apollo 13 mission is a really strong example of why you might need creative problem-solving skills in stressful situations because you might not have the things you

Nair's research focuses on creative problem solving, and in particular, she is interested in developing algorithms that will allow robots to use the objects around them to complete a certain task.

need," said Nair. "Being able to creatively make the things that you need to be able to escape these difficult situations can be extremely important."

That's why she and her colleagues in computing created the "RoboGyver," a robot that combines object recognition algorithms with creative thinking psychology to build tools it might need to complete a task, like a hammer, scoop or pinchers.

RoboGyver, which is a shiny, black robotic arm equipped with a pincher at the end and mounted on a table, is able to use a 3D camera to assess the objects on the table, determine their characteristics and analyze which ones might be able to fit together to create the tool it has been instructed to build. Once RoboGyver has decided which objects to use, it attempts to attach them together to construct the tool.

Nair says she has seen her fair share of comical incidents, in which RoboGyver has tried and failed to combine objects to create a tool. But now, if she instructs RoboGyver to build a certain tool, the robot can do it with some regularity. In the future, Nair hopes to take the project one step further and simply assign the robot a task — and it would have to take care of the rest.

Projects like RoboGyver are helping engineers figure out how to make robots more adaptable. Many existing robots perform very limited and repetitive tasks, such as manufacturing a product on an assembly line. A robot that is able to creatively solve problems would be able to perform more diverse tasks and could even be implemented in the home.

"Even as humans, we do so many creative things around the house," said Nair, who imagines a world with household robots to help out with the chores. "Many times, we might use objects in very unconventional ways. We probably don't consciously realize it. I think it makes sense for something like a household robot to have those capabilities."

There's still a long way to go, and Nair is doubtful that we will see a household robot in our lifetimes. In order for robotics to make advances, she says that there has to be a coevolution of both hardware and software developments. Even if the algorithm used for RoboGyver rapidly improves, the sensor it uses must also become more sophisticated.

Many households around the world already have some robots — smart devices and autonomous vacuums. It might be decades before we have a handy household robot to help with the cooking and cleaning, but the creative algorithm research Nair is doing will get us one step closer.

▶ POLLY OUELLETTE

Twenty years ago, voice-activated personal assistants seemed like far-off fantasy, only seen in comic books and science fiction. Now, we have Siri on our phones, Cortana on our computers, and Alexa in our homes. One Georgia Tech engineer is trying to take personal assistants even further.

A Ph.D. student in the School of Electrical and Computer Engineering, Joanne Truong is forging her own path in the field of robotics.

"I'm really trying to bring all the advancements that Artificial Intelligence (AI) has seen into the robotics world," Truong said. "Sure, Alexa can answer all sorts of questions, but we don't have anything that can really act in the environment and do things for us now. I think it would be really cool if we could have Alexas with limbs so we could ask her things like: 'Hey is my computer in my room? If it is, please go and get it for me.'"

In her current research project, Sim2Real, Truong is working with a team to teach robots to learn real-life skills via simulation. The project hopes to address one of the biggest obstacles in robotics today: creating robots that can learn.

"We don't want to hardcode everything onto the robot, we want to teach the robot to learn on its own," said Truong. "Robots learn through experience. For example, if it moves a certain way and gets to its goal, it remembers that. But in order to teach this way, we need years of experience, which is infeasible to do with a real robot. We leverage simulation in order to make things faster and more affordable to do."

By 3D scanning a real environment and creating a virtualized replica in simulation, the Sim2Real project allows researchers to teach a robot a skill much faster. Instead of physically setting up a robot, having it run the course, and then resetting the experiment up, researchers can simply press a button and run the course virtually. In addition to this, multiple simulations can be run at

the same time, or in parallel, speeding up the learning even faster. The knowledge from the simulations is then loaded onto a physical bot.

"We can now teach a robot to navigate from one point to another in about three days," Truong said. "The robot collects billions of frames of experience, which would take years to do on a physical robot."

The team also works with a PyRobot, which looks like a Roomba vacuum with a 360-degree arm mounted on top. One of the skills Truong and her team has taught the bot is point goal navigation, where it moves from a starting point in a room to a goal point, completely on its own.

While that may seem like a simple feat, Truong explains just how difficult teaching robots simple tasks can be.

"Figuring out all of the things that are required for a robot to understand the sentence 'Go to the kitchen and get me some orange juice' is extremely complex," Truong said. "That simple command has so much more to it. The robot must understand the words you are saying, the reasoning behind what you want it to do, what object you want it to grab, and where in the environment it needs to go. It also needs to understand that orange juice is usually found in the kitchen, therefore it needs to map and learn how to get to the kitchen, needs to learn how to open the fridge and get the orange juice and all that."

Looking forward to the future of her field, Truong is hopeful. "I want to make household robotics a reality for everyone. My future is a world where things are more automated and efficient."

▶ **MAYA FLORES**

"I'm really trying to bring all the advancements that AI has seen into the robotics world. Alexa can answer all sorts of questions, but we don't have anything that can really act in the environment and do things for us now."

Joanne Truong

The Next Frontier in Immunoengineering

Gabe Kwong's research focuses on engineering immunity to transform human health

For patients undergoing transplant surgeries, there is always the immediate concern of the body rejecting the new organ — be it a lung, kidney or heart. There are a few different ways the body can reject an organ, one type being T cell mediated rejection. T cells are immune cells that recognize diseases, or in this case foreign organs, and attack because they sense a danger to the body. In the worst case scenario, the newly transplanted organ is rejected, leaving the patient back at square one.

Traditionally, to track and manage T cell response to organ transplants, also known as grafts, a biopsy is done to look at the tissue to monitor the health of the graft. These biopsies are highly invasive, using large needles that can lead to pain and excessive bleeding. They are also just a moment-in-time static snapshot of the health of the graft. That's where Gabe Kwong's research comes in with his Laboratory for Synthetic Immunity.

"What you really want to know is patient trajectory," said Kwong, associate professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech. "With traditional biopsies, you don't know if the transplant organ is getting better or if it's going to get worse. The non-invasive platform that we are developing measures T cell activity. If T cells are being overactive, you can track that with our miniaturized biological sensors that probe the graft for early signs of transplant rejection. Our approach is a noninvasive solution to the biopsy."

An immunoengineering lab

One part of Kwong's lab is focused on immune sensing, like the T cell sensor for organ transplants, but his work goes further, including engineered T cell therapies for cancer.

"An exciting area of my lab is designing next-generation T cell therapies," said Kwong. "We treat them like a living drug, a smart drug, because those T cells know where to go, can recognize tumor cells and kill them."

Although T cell therapies have the potential to cure patients of disease, a major challenge is that tumors have the uncanny ability to evade immune recognition and even set up a suppressive environment that turn off T cells once they arrive in the tumor.

When a T cell moves into a tumor to try to suppress it, the tumor will switch off the T cells' cancer-killing abilities. To address this, Kwong is developing remote-controlled T Cells that leverage a light beam to control the T cells and turn them back on. The first-generation platform involves making the T cells sensitive to local increases in heat.

"You can use the laser light to heat a tumor and then communicate with the T cells and see if you can make them kill tumor cells better," explained Kwong. "In preclinical models, we are able to induce durable and curative responses."

Commercializing technologies

Kwong's work isn't happening in a vacuum. In 2015, he co-founded a company called Glympse Bio with the goal of transforming disease monitoring and treatment

“AN EXCITING AREA OF MY LAB IS DESIGNING NEXT-GENERATION T CELL THERAPIES. WE TREAT THEM LIKE A SMART DRUG, BECAUSE THOSE T CELLS KNOW WHERE TO GO, CAN RECOGNIZE TUMOR CELLS AND KILL THEM.”

Gabe Kwong

response. Glympse creates sensors designed to replace the biopsy, with the first focus being on liver biopsy. Recently, the company had its first human trials on healthy volunteers.

According to Kwong, with liver fibrosis or fatty liver disease, drug responses aren't instantaneous. With oral drug therapies, it can take months to see any sort of potential change in the progression of the disease. For pharmaceutical companies, they still rely on a liver biopsy and sometimes don't know for months or even up to two years if the drug works and is ready for mass consumption. This is one of the reasons the drug approval process takes so long. But Glympse is trying to change that.

“The long-term goal of the company is to create products that are non-invasive, replacing the biopsy,” said Kwong. “That should help pharma accelerate drug trials. The sensors we are creating have the potential to be predictive so you can get a read out within two weeks of the state of the patient versus waiting 12 months for a biopsy read to determine patient response to drugs.”

Kwong is dedicated to his research, with a passion that started as early as his undergraduate education at UC Berkeley. And it makes him an uncommon engineer as well, given his dedication to the long-term, tireless work that immunoengineering requires.

“You have to be at the top of your game the whole time and be exceedingly patient,” said Kwong. “The timeline for translational research in the life sciences is long, and you aren't going to get instantaneous results. But in 10 years of working with this technology, I haven't lost my drive or passion, and it hasn't gotten less interesting.”

▶ GEORGIA PARMELEE

Brilliant Engineering is in Our DNA

How two engineers are leveraging gene therapies to change the face of medicine

Human genes hold a wealth of information, including the ability to heal the body from within. Engineers throughout the College of Engineering continue to work to unlock the potential hidden within the science of gene therapy — the use of genetic information to treat diseases caused by genes, such as heart disease, cancer, diabetes and more. This experimental technique can be used to help manage or prevent diseases, and in some cases can even negate the need for drugs or surgery.

Protecting the world from infection

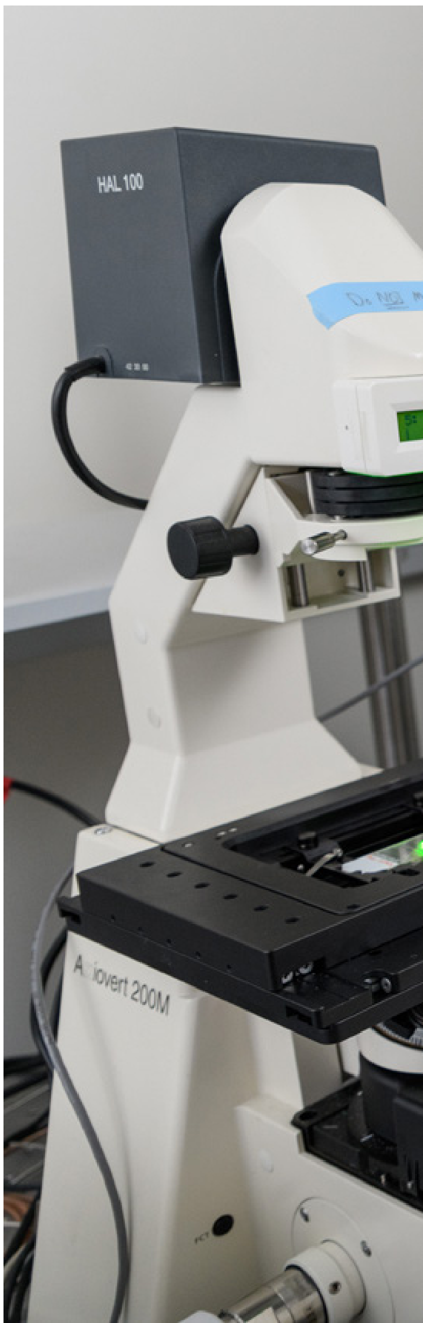
According to the World Health Organization, lower respiratory infections — including influenza — are one of the top 10 deadliest diseases around the globe. Annually, influenza epidemics cause about 3 to 5 million cases of severe illness and between 250,000 and 500,000 deaths.

Philip Santangelo, professor in the Wallace H. Coulter Department of Biomedical Engineering, is principal investigator leading a team on research funded through a $21.9 million grant by the Defense Advanced Research Projects Agency (DARPA) seeking to develop better and faster responses to influenza strains.

Santangelo's work uses gene modulation to turn on or off particular genes in the lungs, making them either more resilient against flu strains or stopping viral replication in its tracks.

"Flu vaccines are developed and administered every year, but they're not always effective, and the disease has wide ramifications across the globe" says Santangelo. "Our research uses RNA-based techniques to manipulate what genes are expressed. For example, we can potentially turn off the receptor that allows the attachment of the flu virus to the epithelial cells inside the lung, stopping the infection process altogether."

SANTANGELO'S WORK USES GENE MODULATION TO TURN ON OR OFF PARTICULAR GENES IN THE LUNGS, MAKING THEM EITHER MORE RESILIENT AGAINST FLU STRAINS OR STOPPING VIRAL REPLICATION IN ITS TRACKS.



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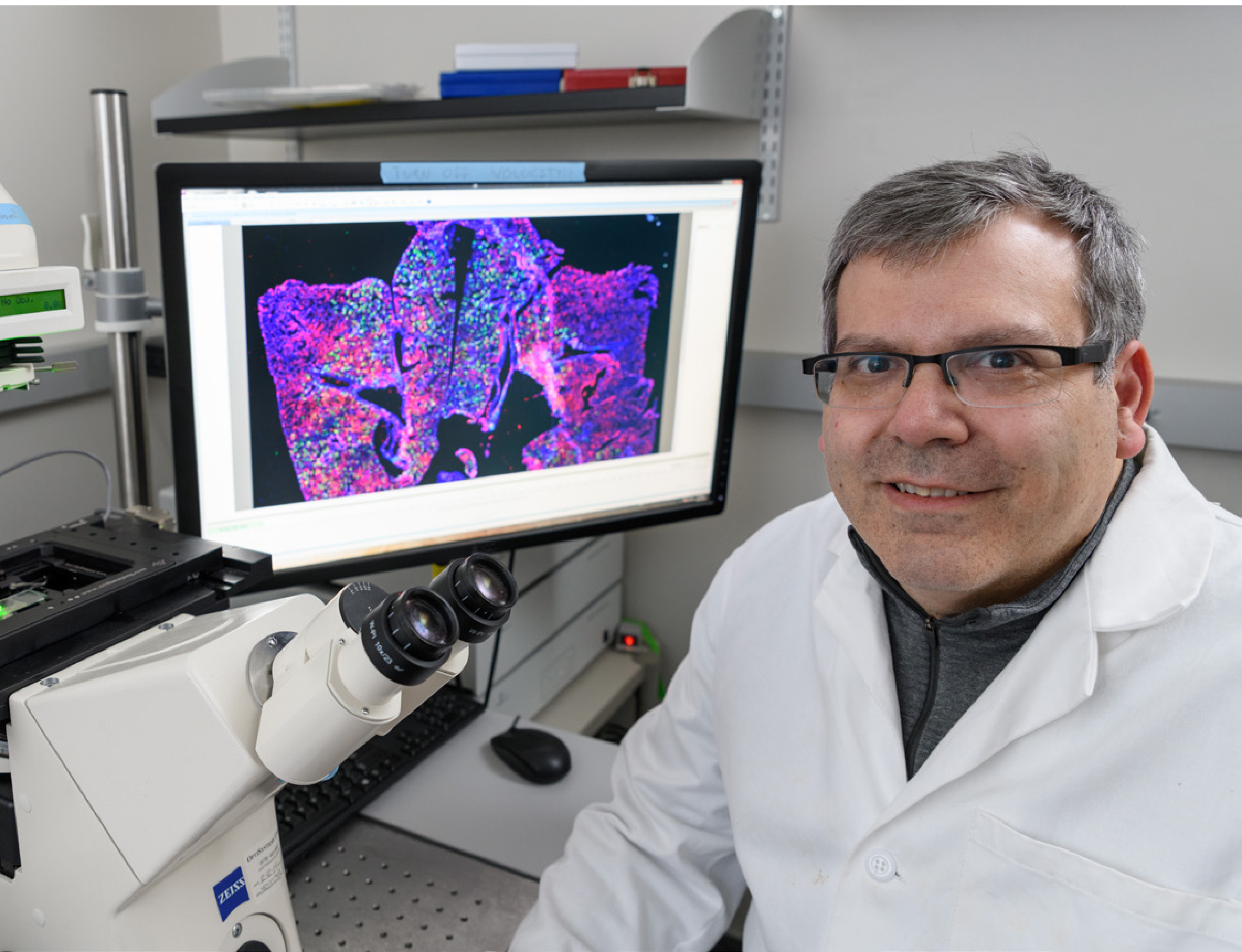
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"MY LAB IS CREATING NANOSTRUCTURED LIPID CARRIERS — BASICALLY TINY SPHERES MADE OF FAT MOLECULES — THAT CAN BE INTRODUCED TO THE BODY IN ORDER TO DELIVER DRUGS TO TARGETED CELLS."

James Dahlman

Santangelo hopes to eventually develop a drug that could be inhaled, using a version of human cells to protect against the flu. According to Santangelo, this drug should be widely applicable for a range of individuals, and potentially even different viral infections — including coronavirus.

"The first animal test takes place in early spring, and, realistically, this kind of therapy could be ready for a phase one human trial in the next four years or so," said Santangelo.

Optimizing drug delivery

Because gene therapy is such a new technology, it can be challenging not only to develop an effective treatment, but also to administer it properly to patients. James Dahlman, assistant professor of biomedical engineering, is developing better delivery systems for gene therapy drugs made out of double-strand DNA or its molecular cousin, single-strand RNA.

"Once these complex gene therapy drugs are created, it's very difficult to get them directly to the diseased cells," explains Dahlman. "My lab is creating nanostructured lipid carriers — basically tiny spheres about 50 nanometers wide made of fat molecules — that can be introduced to the body in order to deliver drugs to targeted cells, such as lungs, heart or brain."

For comparison, a human hair is approximately 90,000 nanometers wide.

These nanostructured lipid carriers can be injected — into the bloodstream, subcutaneously beneath the skin, or intramuscularly like a flu shot — or they can be nebulized into a mist and breathed in, similar to an asthma treatment.

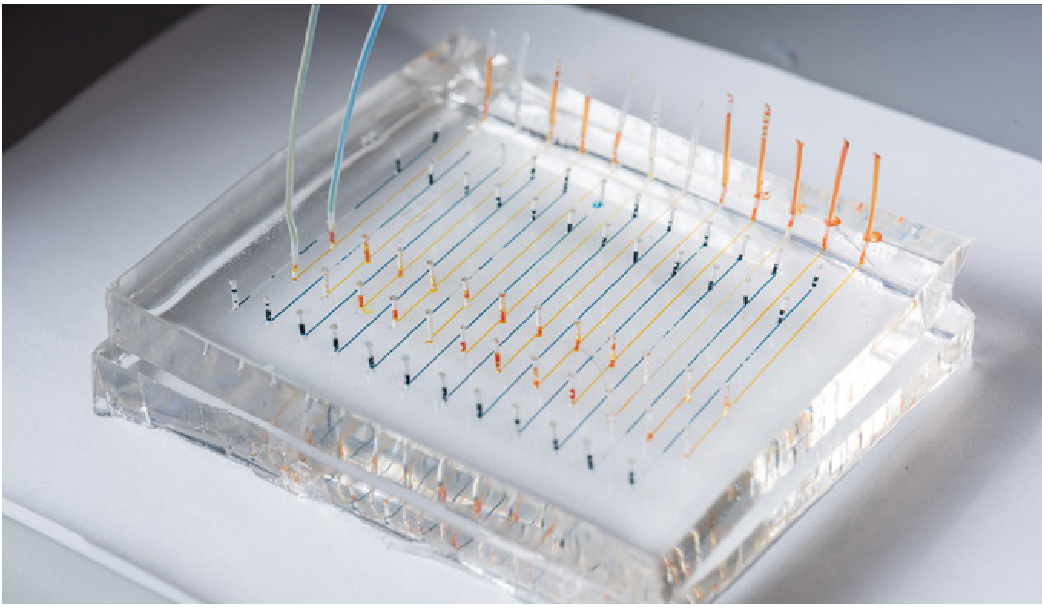
Relatedly, one of Dahlman's most impactful and renowned research projects is using similar nanoparticles in a variety of sizes and of different materials to find the best method by which scientists can deliver specific therapies to cells in the future.

This approach, known as DNA bar coding, was named one of the "Top 10 Emerging Technologies in the World" for 2019 by the World Economic Forum.

To test these nanoparticles for effectiveness, traditionally, researchers would make thousands of different versions filled with the same drug and test them in vitro — that is, in cell culture dishes.

"The issue with this approach is that the delivery you get by spraying particles on cells sitting in a dish does not predict delivery that happens in living animals," says Dahlman. "You are screening for nanoparticle candidates in a way that doesn't predict what you want for an actual outcome."

With Dahlman's groundbreaking method, each different nanoparticle is labeled with a unique DNA barcode (instead of the drug being tested) and administered *in*



Dahlman's lab uses microfluidic chips to create nanoparticles.

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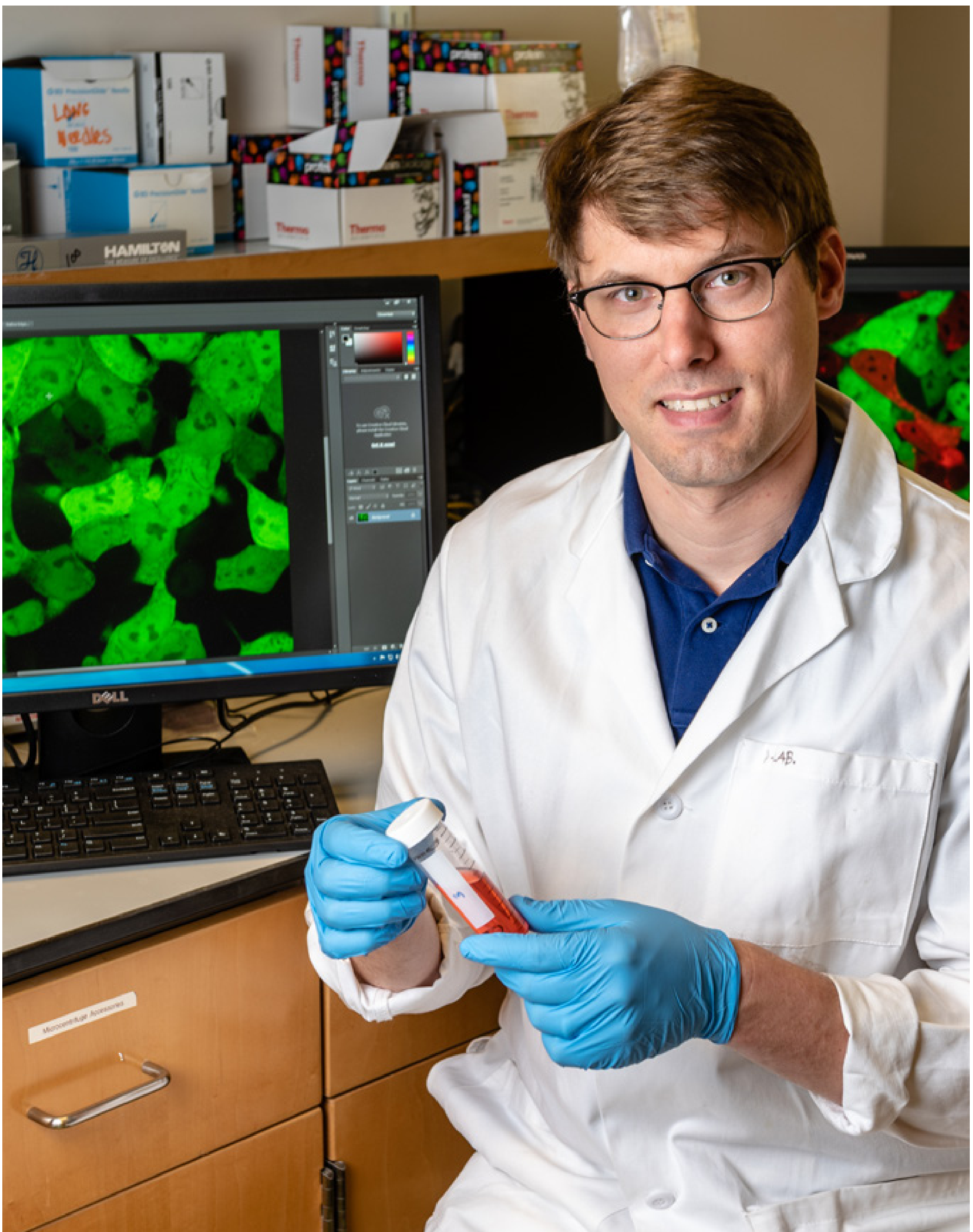


GARY MEEK

vivo, or directly to the animal, isolating the appropriate cells, such as the spleen or lung.

Then, using gene sequencing, Dahlman and his lab can see exactly which nanoparticles did the best job of reaching the intended target. This approach allows researchers to choose the most effective particles of the bunch, infuse them with the gene therapy drug, and then administer them in animals to see the effects of the medication. By using DNA barcodes, the lab can perform hundreds of experiments simultaneously in a single animal. Gene sequencing allows researchers to move more quickly and efficiently towards implementing these therapies in the real world.

The engineered possibilities of genes

The very first gene therapy approved by the U.S. Food & Drug Administration was a treatment for acute lymphoblastic leukemia in 2017; today, at least nine more have been approved for use in the U.S. on a variety of diseases, including a rare form of inherited blindness, spinal muscular atrophy, melanoma and more.

Engineers like Dahlman, Santangelo and others in the Coulter Department of Biomedical Engineering are spearheading groundbreaking innovations and receiving recognition on a national scale. The study and manipulation of genes will continue to have an impact long into the future, especially the more researchers understand about these complex tools.

▶ KATHRIN HAVRILLA-SANCHEZ

Better AI, Better Police Force

How Yao Xie is leveraging artificial intelligence to help fight crime

Data-driven policing is relatively new to the artificial intelligence (AI) scene, and many police departments across the country are interested in using this technology to help solve some of their systemic challenges, such as privacy protection, better resource allocation and bias reduction.

Yao Xie, associate professor and Harold R. and Mary Anne Nash Early Career Professor in industrial and systems engineering, and associate director for the Machine Learning Center at Georgia Tech, has been working on data-driven policing for years. Funded by the Atlanta Police Department and the City of South Fulton, GA, in an effort to use data to solve some of their larger challenges, Xie has been working on this area since late 2016, leveraging AI to help make policing more effective and efficient.

An important part of police investigations is to understand whether cases are related in order to catch serial or organized crime operators. However, the amount of time it takes one or several officers to pore over thousands of cases looking for similarities is impractical. So, Xie's first project with the Atlanta Police Department was to develop and help implement an algorithm that could find these correlations faster, narrowing down the number of cases that need to be individually examined from thousands to 50 or so.

"Back in 2017, there were 23 similar house break-ins in the North Buckhead neighborhood in about a 5-mile radius," Xie explains. "There was a clear pattern in the way this individual broke in and ransacked particular rooms. By using this algorithm, Atlanta police were able to narrow down the cases they examined and link all of these crimes together and attributed them to one perpetrator, who was caught and prosecuted."

Redrawing police district boundaries

Another segment of Xie's work with the police — optimizing police zone design — sought to make police patrolling more effective.

Police districts across the country are generally divided into geographical zones, contained or designated by imaginary borders. Each zone is then subdivided into "beats," or the smaller territories that individual officers are assigned to patrol at different times of the day.

The Atlanta Police Department has six different zones — Northwest, Southeast, Southwest, Downtown and more — which are broken out into approximately 80 beats, with roughly one patrolling unit per beat and one or two officers in each car. When someone calls 911, the dispatcher must decide who is the closest and most available unit to send to respond.

"How the boundaries are drawn becomes very important because of the limited number of police officers that are tightly controlled by staffing budgets," says Xie. "The design the department was working with hadn't changed in 10 years. The population is now very different, as well as other factors like traffic patterns and changes in police workload."

Xie spent a year looking at the information the Atlanta Police Department had gathered about their patrolling layout, and she used statistical machine learning and AI to solve their optimization problem.

By having an algorithm work through massive-scale, real-world data from 2011 through 2018, with millions of instances and 200 unique categories, the department was able to redraw their zone lines in March of 2019 with a better understanding of police workload and predicted response times — with crime rates dropping as a result.

In 2020, Xie and the Atlanta Police Department are continuing to monitor and understand how effective the new zone design is now that it has been in place for more than a year. In addition, Xie worked with another police department in the City of South Fulton to redesign their beats, which had not been changed for more than 40 years. The design was passed by the City Council in January 2020 and implemented afterward.

"We're working together to do systematic analysis on where we see the most improvement, where we're not, and what we can do better," says Xie.

▶ KATHRIN HAVRILLA-SANCHEZ

ALLISON CARTER

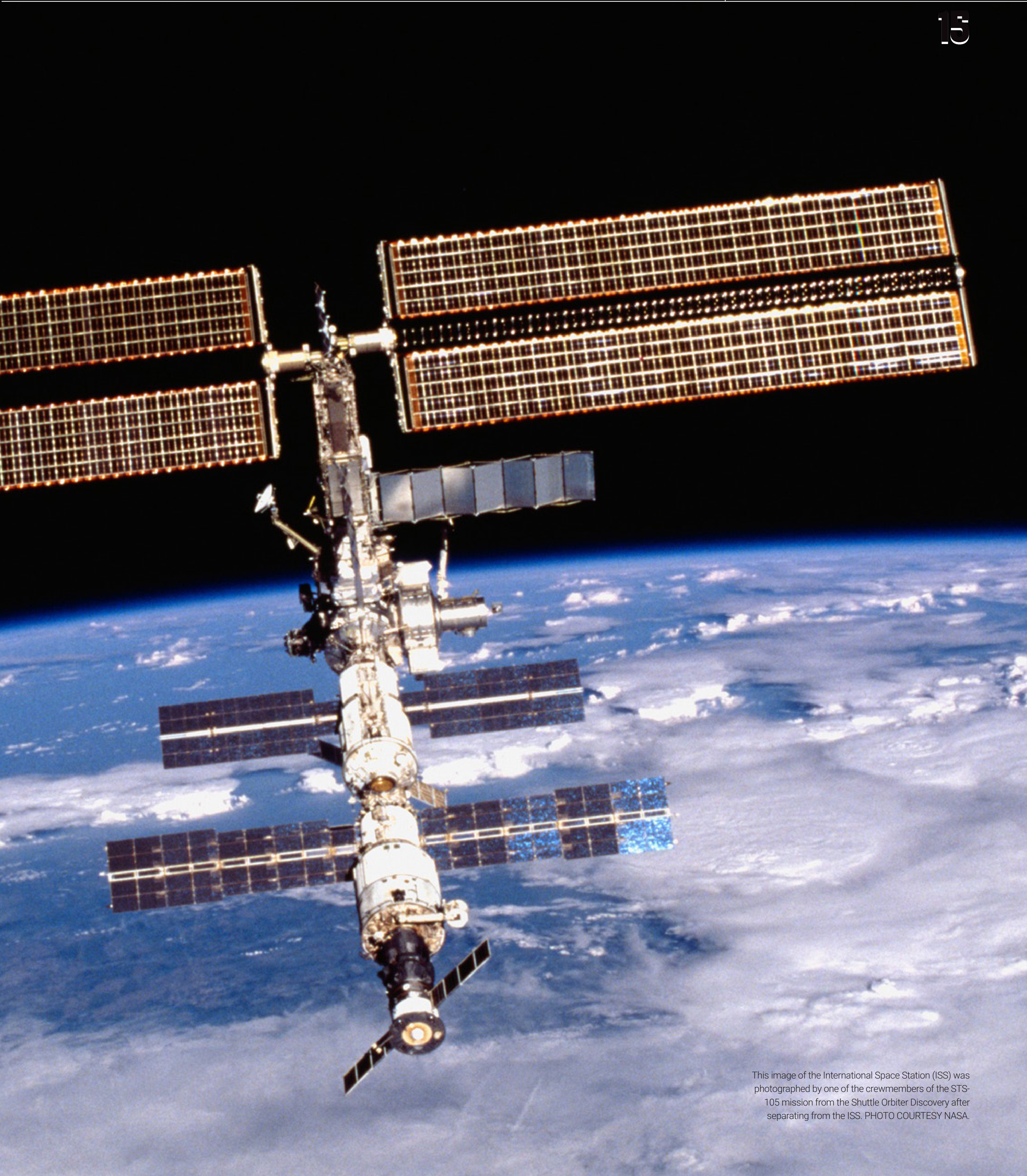
XIE SPENT A YEAR LOOKING AT THE INFORMATION THE ATLANTA POLICE DEPARTMENT HAD GATHERED ABOUT THEIR PATROLLING LAYOUT, AND SHE USED STATISTICAL MACHINE LEARNING AND AI TO SOLVE THEIR OPTIMIZATION PROBLEM.

ALLISON CARTER

“HOUSTON, WE HAVE INNOVATION”

HOW GEORGIA TECH ENGINEERS ARE SHAPING THE SECOND AGE OF SPACE EXPLORATION

WORDS: DESIRINA FREW
ILLUSTRATION: JOEL KIMMEL



This image of the International Space Station (ISS) was photographed by one of the crewmembers of the STS-105 mission from the Shuttle Orbiter Discovery after separating from the ISS. PHOTO COURTESY NASA.

One October day in 1957, Sputnik I entered Earth's orbit, and the Space Age officially began. Now, as the 2020s roar in, the world is on the cusp of a second great age of space exploration. And it's one that Georgia Tech engineers are working to shape.

The first space age was dominated by a few major players, namely, nations with the resources to manage this immense task. The focus was on arrival — launching a satellite, setting foot on the moon, venturing beyond the solar system — and where crews were involved, a safe trip home.

In comparison, the second space age is an open-ended, open-access, joyfully riotous free-for-all. And the emphasis is on establishing a more lasting presence.

Professor Glenn Lightsey in the Daniel Guggenheim School of Aerospace Engineering is overflowing with excitement at the possibilities: the scientific exploration, the extraterrestrial outposts, the goods and services delivered to Earth from orbiting stations above. But "the most exciting thing," he says, "is how much more accessible space is today and will become in the future."

More missions are planned than ever before. NASA will soon launch another Mars rover and send a spacecraft to Saturn's moon, Titan. Private-sector companies like SpaceX, Boeing and Virgin Galactic are planning both crewed and autonomous explorations and executing daring missions, like Elon Musk's vision to ferry people to Mars in the coming decades. And many more space agencies around the globe — India, China, Europe and others — are launching their own expeditions.

What's driving this revolution? For one, it's a shocking drop in launch costs, which has enabled an outpouring of both collaboration and competition. Over the past decade, it's become 20 times cheaper to get a spacecraft out of the mighty pull of Earth's gravity and into the weightlessness of space. Thanks in part to work by Lightsey and his colleagues, it's becoming more affordable still.

This shift in affordability and accessibility, Lightsey says, will lead to discoveries we haven't anticipated, as autonomous spacecraft venture further and advance research aims on distant planets, asteroids and moons.

An expanded human presence in space will change life on Earth, too. A larger network of deep space communications satellites will expand global access to high-speed data. Orbiting manufacturing centers could produce advanced materials that are difficult to manufacture within Earth's gravity. Space-based solar power stations could soak up the sun's strongest rays to produce cheap renewable energy for use here on Earth.

The mighty miniature spacecraft

To help achieve some of these aims, Lightsey's team in the Space Systems Design Lab is building miniature autonomous spacecraft that can match the performance of a much larger space vehicle.

"The cost of doing a mission in space is driven by the size of the spacecraft," Lightsey says. "The bigger the spacecraft, the more expensive it is to make." As with computers and cellphones, the pieces that power spacecraft are shrinking by the year, making miniaturization possible.

Lightsey's team is using advanced technologies and new materials to build the smallest propulsion systems ever. Right now, they're building one for NASA: a propulsion system small enough to fit in the palm of your hand, engineered to power a satellite the size of a briefcase.

NASA plans to launch this mini satellite into orbit around the moon, where it will search for ice. If ice is discovered — with its promise of water — it could radically expand human exploration by ensuring access to a key ingredient for survival and infrastructure. No need to transport water to space at the cost of thousands of dollars per kilogram.

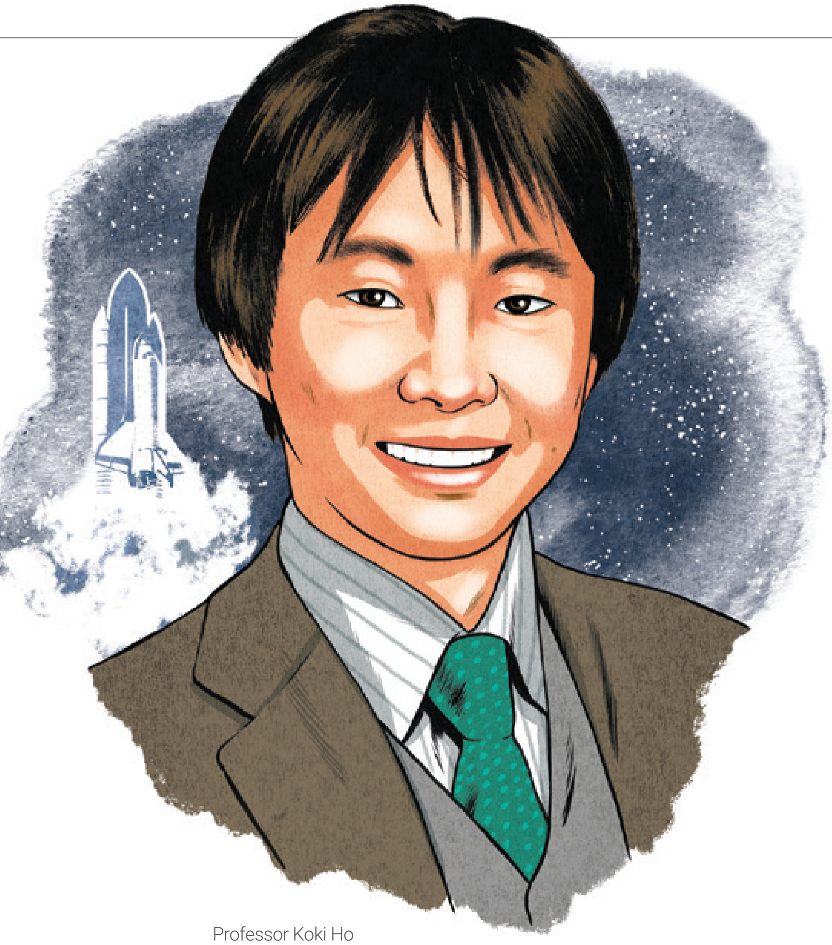
In the meantime, Lightsey and his team need to work out the details that will allow their small propulsion system to attain enough power to maneuver that briefcase-sized object into orbit. Designing something so tiny and powerful is extraordinarily hard.

"It's a small gas tank, so the propellant must be very efficient," Lightsey explains. "Things that are very hot are situated next to things that are very cold. Everything that is difficult to build in a big thruster becomes harder when the environment is smaller. It's all much more integrated, and you can't just design 10 systems separately."

Miniaturizing the system that launches a satellite is just one part of Lightsey's research. His lab is also examining ways to deploy swarms of small satellites. The goal is to create a constellation of semiautonomous satellites that together can work more flexibly and effectively than a single larger satellite. To meet this challenge, his team will have to solve some of the same problems that plague designers of self-driving cars here on Earth.

Professor Glenn Lightsey

Lightsey's team is building a propulsion system small enough to fit in the palm of your hand, engineered to power a satellite the size of a briefcase.



Professor Koki Ho

"Space mission design has become much more complex than before, and we may need to provide new tools in response and a new way to think about space mission design itself."

Koki Ho

"In many cases, you can do things more effectively with multiple vehicles working together than a single vehicle trying to do it by itself," Lightsey says. The approach, called satellite formation flying, offers many advantages. Small, single-purpose devices are cheaper to build, easier to replace and can cover multiple angles and locations at the same time. Potential applications for these satellite swarms include next-gen communications networks, high-resolution telescope arrays and improved weather forecasting.

Modeling missions in 3D — and zero-G

Yet, as more vehicles head to space, the logistics of managing space traffic are becoming a lot more complicated. That's the problem Lightsey's aerospace engineering colleague, Koki Ho, is working on.

The assistant professor heads up Georgia Tech's new Space Systems Optimization Group. Backed by research grants from NASA and the U.S. Department of Defense, Ho is applying mathematical modeling and machine learning to create problem-solving frameworks that conquer logistical challenges in space.

In the past, planning a spacecraft's journey has focused on Point A (Earth) to Point B, and sometimes the return. But with more traffic up there, such planning needs to change.

"With more vehicles and destinations, the problem is more complicated than optimizing trajectory," Ho says. Planning space missions as networks rather than single voyages, he says, requires a more mathematically rigorous approach to mission design. Perhaps even a new paradigm.

Take the example of "on-orbit servicing." Usually, when something goes wrong with an orbiting spacecraft, a service mission is sent to fix it. When the job is done, that service spacecraft returns to Earth.

But as more spacecraft like Lightsey's autonomous satellites enter permanent orbit, such an approach is no longer so efficient. Instead, you need helper spacecraft to remain in orbit, too, where they can reach their targets more quickly and cheaply. But where should these helpers be stationed, and what servicing capacity should they have?

Ho compares the problem to the fire stations here on Earth. No one knows exactly when or where a fire will break out. That's why fire stations are strategically spaced, taking into account where fires might happen. Each needs to have the optimal number of vehicles and firefighters to respond quickly when the time comes.

Imagine a space repair infrastructure that looks a little like that — strategically-spaced hubs that house optimally-sized repair vehicles along with an optimal amount of equipment, so help is never too far away. Ho is developing such an approach.

"Many of our research questions are driven by real problems," says Ho. "The common theme behind all these challenges is complexity. Space mission design has become much more complex. In response, we may need to provide new tools and a new way to think about space mission design itself."

The next big leap? Crewed missions to the moon and Mars, allowing humans to explore the terrain and build bases. But first, scientists need to answer some big questions about the impacts of long-duration space travel on the human body — how humans react to life in microgravity for a month or longer.

Professor Ross Ethier

The leap toward life on Mars

Right now, our best approximation is life on the International Space Station, which houses an international crew of six people, 250 miles above Earth. Each astronaut usually stays on the station for about six months. This living laboratory shows the many ways that living in space can take its toll. Muscles deteriorate, bones become less dense and exposure to cancer-causing radiation increases.

Another toll is an eye condition that causes blurred and deteriorating vision, and can ultimately end in blindness. It's called SANS, for Spaceflight Associated Neuro-Ocular Syndrome, and Professor Ross Ethier is working with NASA to understand its causes.

About 40 percent of astronauts experience these symptoms after spending a month or longer in microgravity. But some never do. "That's one of the mysteries of SANS," says Ethier, a GRA Eminent Scholar in the Wallace H. Coulter Department of Biomedical Engineering. "It's a very mysterious condition. We don't really understand why this occurs."

One major challenge is getting a good view of the condition. For a variety of reasons, conducting an MRI in space is not an option. So, Ethier and his team recruited volunteers to undergo MRIs while lying in an inverted position, with heads tilted downwards. This changes the pressure around the brain, mimicking some of microgravity's effects and allowing a closer look at the eyes under such conditions.

NASA also gives astronauts MRIs before and after spaceflight, collecting important data on its physical effects. Ethier's team has been given access to this data as well, allowing them to illuminate properties of the optic nerve and the sheath that protects it. Ethier aims to determine what makes some astronauts more vulnerable to SANS than others and discover countermeasures to protect all space travelers.

"This has to be solved before we can venture out farther," Ethier says. "I think they're most worried about a Mars mission. It's not like you can just whip back to Earth and get a new pair of glasses."

The 2020s are here — with a bang — and one thing is certain: the human desire for exploration is as pressing as ever. As craft and crews from around the globe venture farther into space and stake their footholds, the opportunities will only multiply.

And so will the challenges. For engineers, the decade ahead is filled with plenty of successes to celebrate, as well as new intriguing problems to solve. ◂

ENGINE

SOLUTION
FOR COVID-1

SHANNON YEE

ERING

IS
19

As the COVID-19 pandemic creates unprecedented challenges and takes an enormous toll on our healthcare system, engineers across the College of Engineering are heeding the call to put their skills to the test. Our researchers are creating personal protective equipment (PPE), respirator parts, ventilators and more. Here are just a few stories of what the College is doing to fight COVID-19. ▶

> Engineering Solutions to COVID-19

THE FIGHT AGAINST COVID-19

PPE and other medical supplies to manage COVID-19 complications are in short supply, locally, as well as globally. Many engineers from Georgia Tech and beyond are doing their part in the fight against COVID-19, and Kolby Hanley is one of them. A recent Materials Science Engineering graduate, Hanley has turned his company's warehouse, using all of his 3D printers, into a rapid response center to create respirator parts.

"Normally for manufacturing efforts, it's a two-week lead time, and that's fast by industry standards. With just-in-time manufacturing you have two days to get ahead of it. The faster we can manufacture and make kits into an open source design, it will help others create the parts in an exponential and impactful way." — Kolby Hanley, a recent School of Materials Science and Engineering graduate

GEORGIA PARMELEE

> **"THE FASTER WE CAN MANUFACTURE AND MAKE KITS INTO AN OPEN SOURCE DESIGN, IT WILL HELP OTHERS CREATE THE PARTS IN AN EXPONENTIAL AND IMPACTFUL WAY."**
>
> Kolby Hanley

Kolby Hanley at UltraView headquarters with the respirator kits.

Emory University physician Jay Sanford and his wife Joanne are seen testing the intubation cover that Sanford and Aerospace Engineering doctoral student Lee Whitcher recently refined.

> Engineering Solutions to COVID-19

WHAT ENGINEERS DO IN A CRISIS

The same COVID-19 virus that has emptied the streets of Atlanta has transformed aerospace engineering doctoral student Lee Whitcher into a PPE designer, a nonprofit foundation founder and a community organizer — all in about two weeks. Emory University physician Jay Sanford has been working with Whitcher to create the intubation cover — a lightweight, polycarbonate enclosure originally devised by a physician in the Philippines. While the two refine this equipment, Whitcher has been designing a distributed manufacturing network that will ultimately allow volunteers to fabricate hundreds of covers in their homes, using simple tools and directions.

"When this all hit, and we moved to remote instruction, I realized it was a great opportunity to focus on my dissertation uninterrupted. I set myself up in the dining room where my better half, Kirstin, a school teacher, was also working. But I couldn't shake the feeling that I have a particular set of skills and experience that could make a real difference in the fight against COVID-19." — Lee Whitcher, Ph.D. candidate in the Daniel Guggenheim School of Aerospace Engineering

▶ KATHLEEN MOORE

"I COULDN'T SHAKE THE FEELING THAT I HAVE A PARTICULAR SET OF SKILLS AND EXPERIENCE THAT COULD MAKE A REAL DIFFERENCE IN THE FIGHT AGAINST COVID-19."

Lee Whitcher

Researchers evaluate operation of a simple, low-cost ventilator based on the resuscitation bags carried in ambulances.

> **Engineering Solutions to COVID-19**

SIMPLE, LOW-COST VENTILATOR BUILDS ON AVAILABLE RESUSCITATION BAGS

A simple, low-cost ventilator based on the resuscitation bags carried in ambulances — and widely available in hospitals — has been designed by an international team of university researchers. The device, which is powered by a 12-volt motor, could help meet peak medical demands in the industrialized world and serve resource-constrained countries that don't have supplies of conventional ventilators.

"We are adapting the bag-valve-mask (BVM) resuscitators that are already in place, designed to be manually squeezed for reviving a patient. We are providing the mechanical assist that allows the bags to be squeezed continuously for days rather than for short periods of time. We are using infrastructure already in place." - Shannon Yee, associate professor in the George W. Woodruff School of Mechanical Engineering

▶ JOHN TOON

> Engineering Solutions to COVID-19

SUPPLYING FACE SHIELDS TO THE MEDICAL COMMUNITY

The Wallace H. Coulter Department of Biomedical Engineering at Emory and Georgia Tech serves as a bridge between healthcare needs and broad technical know-how at Georgia Tech, and researchers are talking regularly with hospital systems to discuss their needs. So far, hand sanitizer, disinfectant wipes, face shields, respirator masks and ventilators have been identified as critical needs. Using resources of the Flowers Invention Studio — such as 3D printers — the group has already produced 1,000 face shields and is preparing to fabricate thousands more in the form of kits that hospitals can assemble.

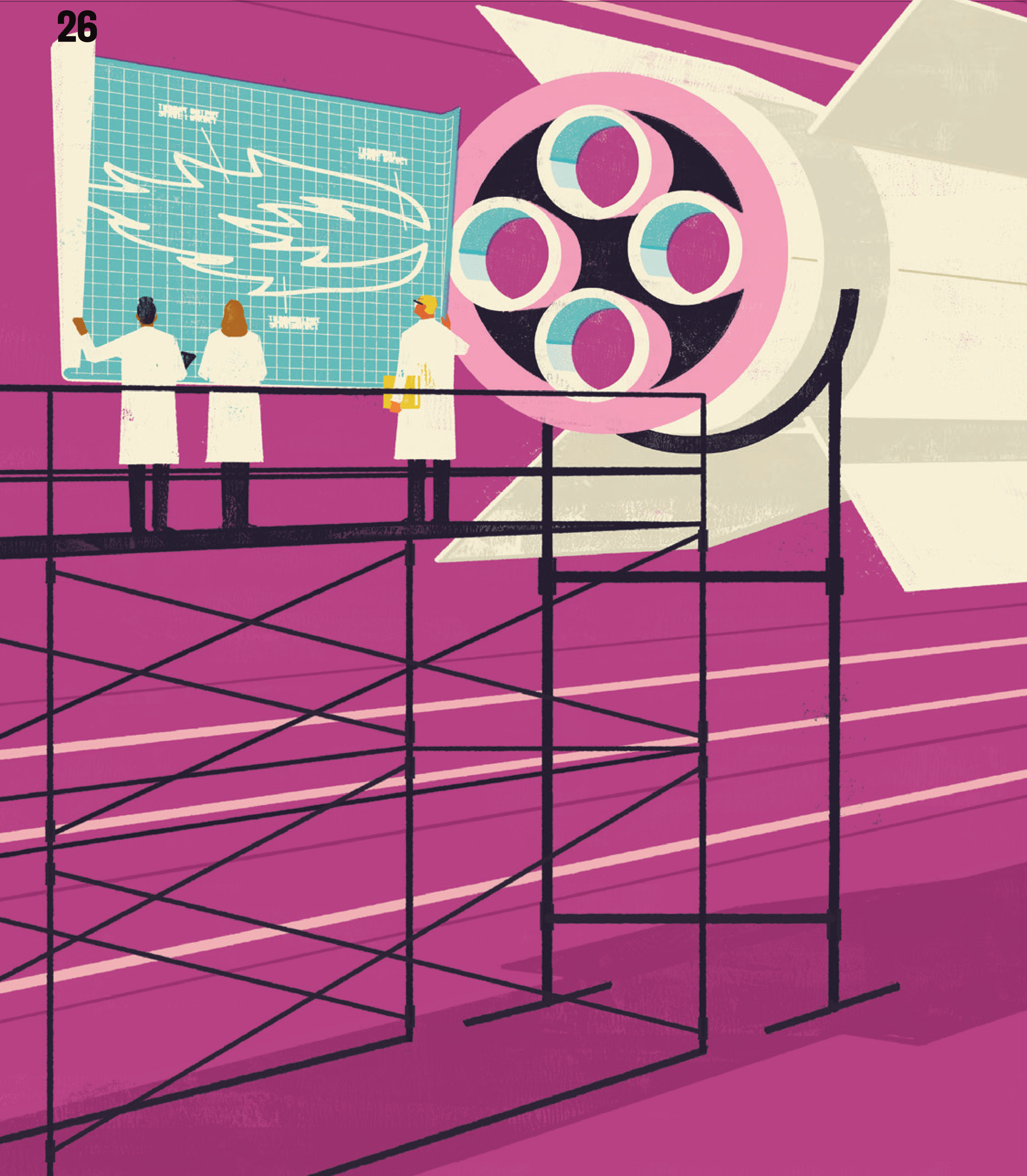
"The Georgia Tech mechanical engineering team is working to modify open source face shield designs so they can be manufactured in high volumes for the rapid response environment that COVID-19 requires. Our team has modified these designs using a range of product and process optimization methods, including removing certain features and standardizing tool use. By working on cross-functional and cross-disciplinary teams and directly involving healthcare practitioners and high-volume manufacturers, we will be able to respond to this effort at the scale and speed required." - Christopher Saldana, associate professor in the George W. Woodruff School of Mechanical Engineering.

JOHN TOON

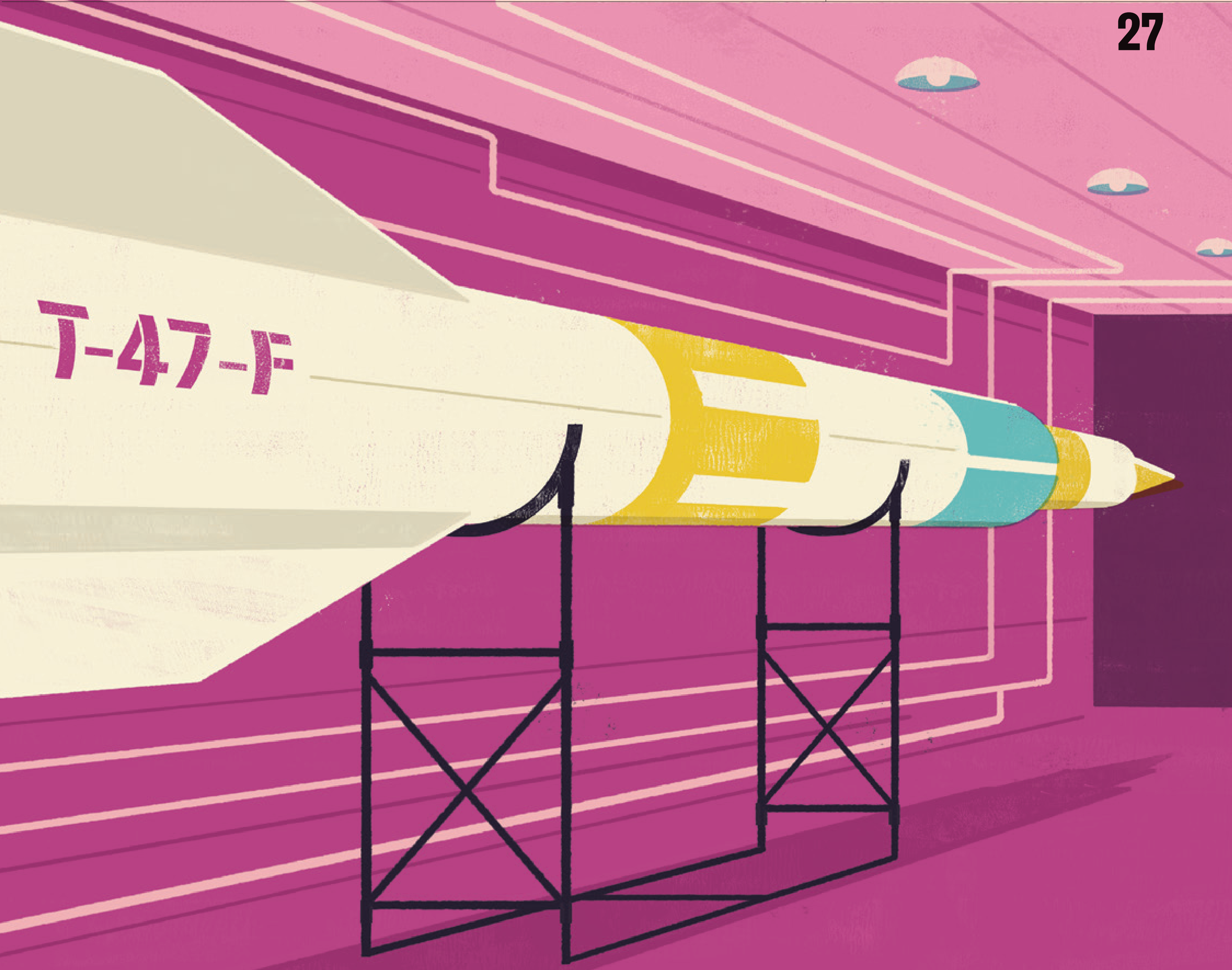
A laser cutting machine in the Flowers Invention Studio is used to create frames for the face shields.

"BY WORKING ON CROSS-FUNCTIONAL AND CROSS-DISCIPLINARY TEAMS AND DIRECTLY INVOLVING HEALTHCARE PRACTITIONERS AND HIGH-VOLUME MANUFACTURERS, WE WILL BE ABLE TO RESPOND TO THIS EFFORT AT THE SCALE AND SPEED REQUIRED."

Chris Saldana



WORDS: KATHRIN HAVRILLA-SANCHEZ
ILLUSTRATION: CHRIS GASH



WARP SPEED AHEAD

AT FIVE TIMES THE SPEED OF SOUND, GEORGIA TECH ENGINEERS PUSH HYPERSONICS TO THE LIMIT

The area of hypersonics — incredibly fast-moving vehicles that travel over Mach 5, or five times faster than the speed of sound — is experiencing a renaissance of research and development interest. Under the advisement of Chaouki Abdallah, Georgia Tech's executive vice president for research, the university is creating a task force on "hypersonics as a system," led by Devesh Ranjan, professor in the George W. Woodruff School of Mechanical Engineering. Thanks to an abundance of faculty skilled in engineering areas, including aerospace, chemical, materials and more, Georgia Tech is uniquely positioned to help this re-burgeoning industry soar. Ranjan's research group is working on understanding the turbulence behavior in extreme environments encountered in air-breathing hypersonic systems.

"Lighting a match in a hurricane"

The applied research initiatives for this new task force at Georgia Tech will fall under a number of diverse focus areas, from creating stronger and more heat-resistant materials, to developing more sensitive and effective guidance systems, to innovating more successful propulsion techniques.

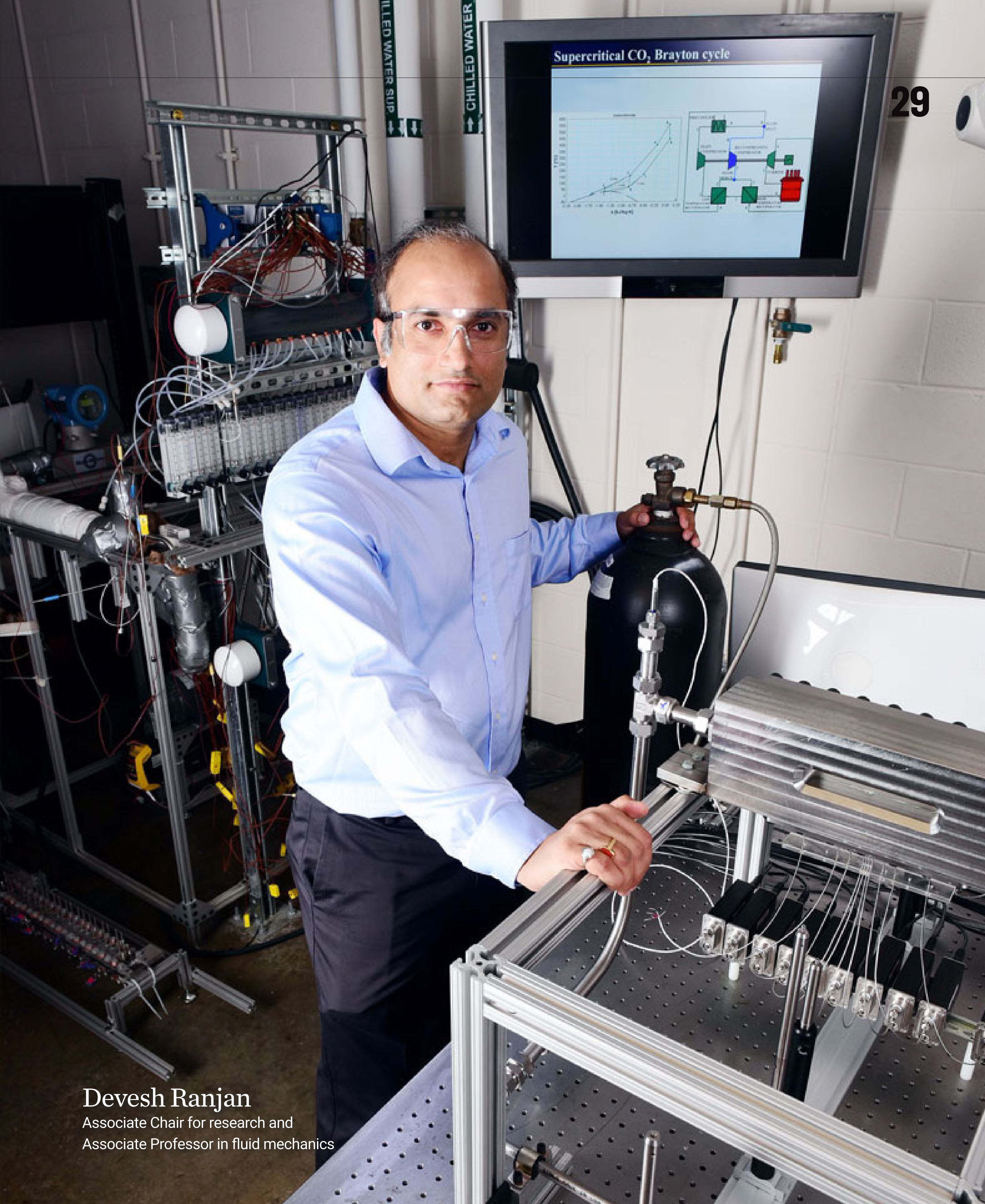
Adam Steinberg, associate professor of aerospace engineering, is one faculty member working on propulsion and developing ways to make the engines in hypersonic vehicles work better and more reliably at intense speeds.

"The combustion inside a hypersonic engine is a bit like trying to light a match and keep it lit in a hurricane," says Steinberg. "There are interactions between fluid dynamics, thermodynamics and chemistry that effect our ability to power the engines and provide thrust."

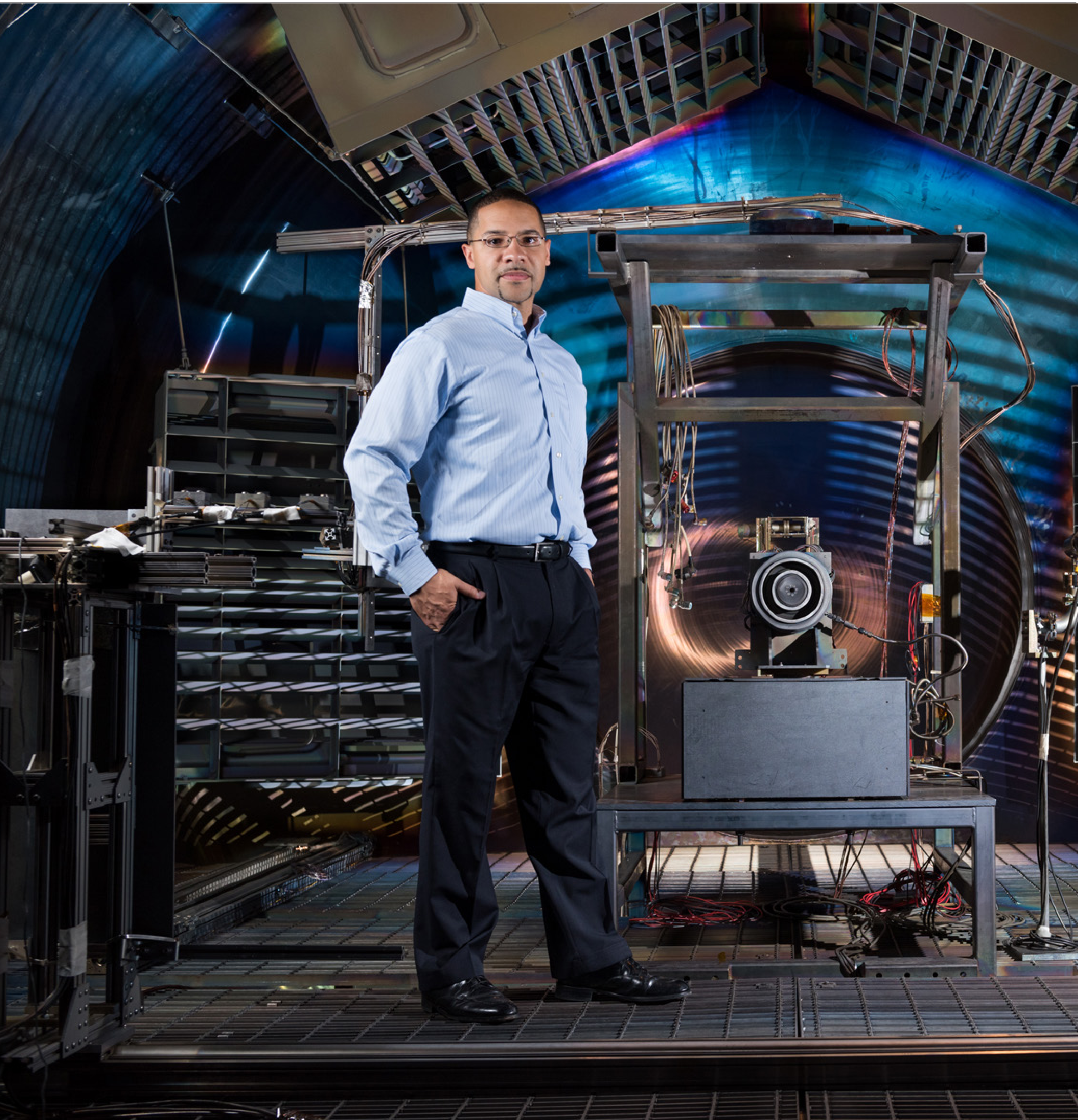
As an experimentalist, Steinberg employs model engines built out of transparent materials so he and his team can clearly see what's happening inside. These models are tested inside high-speed wind tunnels at Georgia Tech's Combustion Laboratory in conditions that as closely as possible replicate hypersonic flight.

"We'll use lasers to measure the fluid mechanics and chemistry inside of the models, which then provide data by which we can validate computational simulations of how these engines — and the vehicles they would power — would perform in the real world," says Steinberg.

GARY MEEK



Devesh Ranjan
Associate Chair for research and
Associate Professor in fluid mechanics



“It’s about finding the best combination of team members from industry, government and academia to get focused research and applicable results [in hypersonics].”

Mitchell Walker

Mitchell Walker
Professor of aerospace engineering
in the High-Power Electric Propulsion Laboratory

ROB FELT

Keeping in contact

Another engineer taking part in the hypersonics research task force is Mitchell Walker, professor of aerospace engineering, who is working with plasma diagnostics and applying them to hypersonic load.

“Within hypersonics, the incredible speed means that the air around the vehicle gets so hot that it ionizes, which creates plasma,” explains Walker. “The air places a huge thermal load on the vehicle, and the plasma can make it difficult to maintain effective communication.”

Because this hypersonic flow surrounding the vehicle is moving at such fast speeds, it’s a harsh environment to take measurements: Any probes used will interrupt the flow pattern and cause incorrect results or potentially break off altogether.

Walker and his team get around this problem by using terahertz time-domain spectroscopy (THz-TDS), in which they shoot a pulse of radiation at terahertz frequencies into the plasma. By assessing the measured plasma density, they can figure out what it would take to communicate with the vehicle under those conditions using calibrated computational models.

From Walker’s perspective, one of the challenges of hypersonics research at the moment is finding the right people.

“Since the 1990s, many universities and industries have deprioritized some of the research areas that are crucial to hypersonics — plasma diagnostics, scramjet engines and so forth,” says Walker. “There isn’t a wealth of people directly involved in hypersonics, but more so

“We have the expertise and the infrastructure in place today to create the innovations that industry is looking for tomorrow.”

Adam Steinberg, Associate Professor in aerospace engineering

people who have the right kind of research background to move into it. Now it’s about finding the best combination of team members from industry, government and academia to get focused research and applicable results.”

From lab to marketplace

From Ranjan’s point of view, Georgia Tech and the surrounding community stand ready to become a hub for this growing industry.

“We are thinking big, and Georgia Tech is acting as a catalyst for the development of some really exciting research,” says Ranjan. “Some of the work that we’re doing will also have impacts on fields such as planetary entry, materials science, even commercial travel far down the road.”

Beyond faculty members, Georgia Tech’s task force also includes Steve Justice, executive director of the Georgia Centers of Innovation, to help move some of these discoveries and technologies more effectively into the commercial space.

“The hypersonics task force is centered at Georgia Tech because of its strong concentration of resources, which are a function of the people who work and study here,” says Steinberg. “We have the expertise and the infrastructure in place today to create the innovations that industry is looking for tomorrow.”

While these are just a few examples of the wide breadth of hypersonics work taking place, Georgia Tech faculty will continue to use these resources to refine applied research in hypersonics-related areas, such as thermal protection systems, navigation, aerodynamics and more. ◂

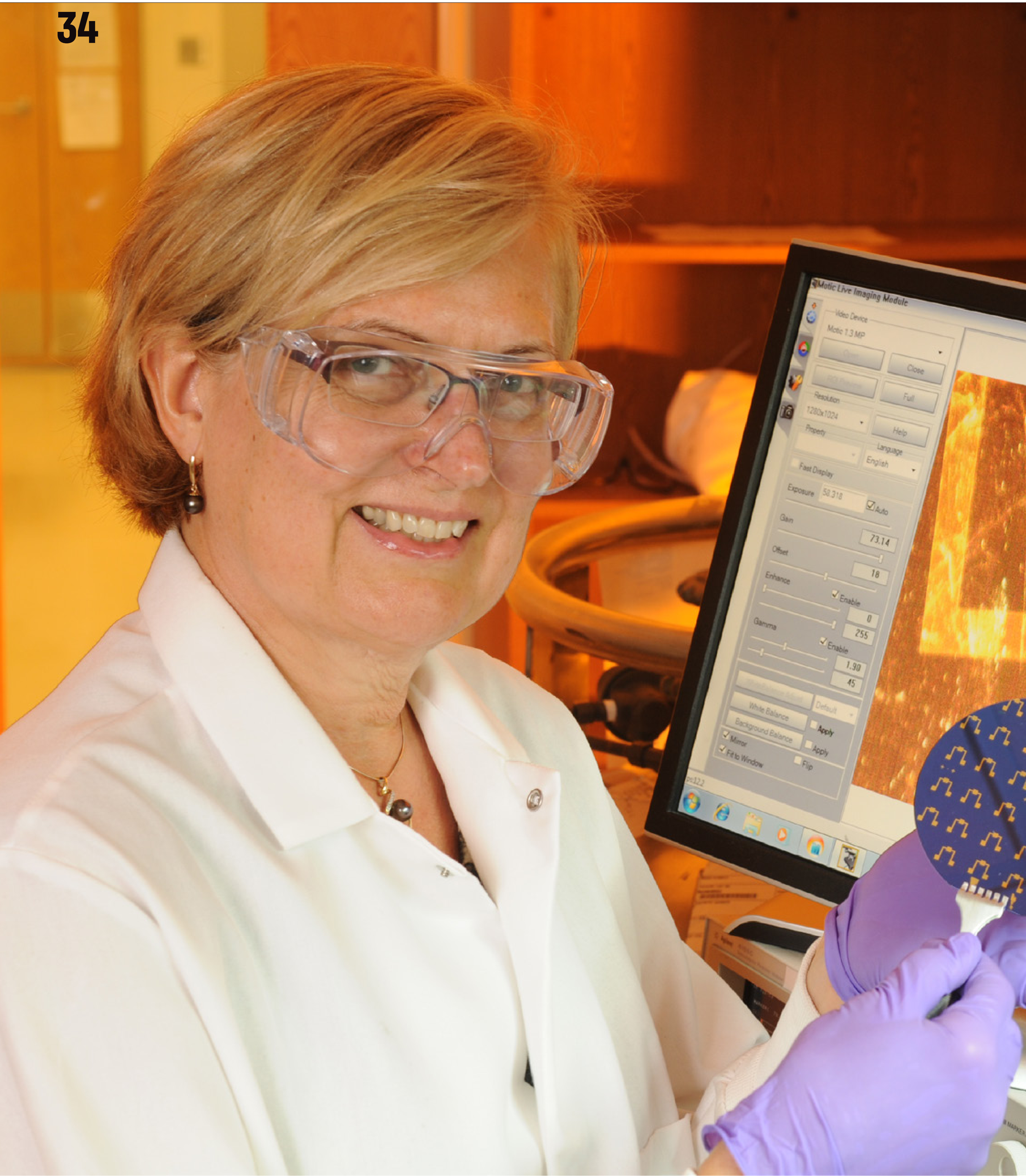
HYPERSONICS AT GEORGIA TECH

The research innovations from the hypersonics task force members are complementary to other projects at Georgia Tech in recent years:

- **Odin’s Eye**
  The “Odin’s Eye” internal research and development program began in 2019 to develop a hypersonic cruise missile system for mobile, fleeting and time-critical targets.

- **Collaborations**
  The Institute is involved in a number of hypersonics collaborations — including working with the University of Tennessee Space Institute — to join the Center for Test Sciences’ efforts to organize a university consortium. Georgia Tech has developed a subsequent relationship with Lockheed Martin as a part of this joint work.

- **Grand Challenges**
  The Aerospace Systems Design Laboratory organized a number of 2020 Grand Challenges in which student teams are tasked to improve upon the multidisciplinary design and optimization environment that would allow them to better create vehicles and missiles with hypersonic capabilities.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Gamma
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45
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White Balance
Apply
Background Balance
Apply
Mirror
Fit to Window
Flip

WORDS: MICHAEL BAXTER

MINDS OVER MATTER

AS THE DRIVE TO INVENT NEW MATERIALS SHIFTS INTO HIGH GEAR, THE VIEW OF TOMORROW IS INSPIRING

ChBE Professor Elsa Reichmanis. GARY MEEK.

The world we imagine tomorrow sometimes seems locked in a dream. In this world, the oceans are free of plastic, the skies cleared of carbon. Our kitchen counters can fend off germs. We pack the electric car for vacation, knowing we can travel farther without recharging. As we age, implanted medical devices are embraced by our bodies, happily integrated into tissue and bone.

Such a world remains in the distance, but it's coming into view much quicker, thanks to the collective, collaborative minds of researchers in the School of Materials Science and Engineering (MSE). So much of what we see around us — the physical matter of everyday life — will change because the field itself is evolving. What was once a trial-and-error realm of pure experimentation has opened up, ushering in a new era of accelerated discovery.

The fuel for this progress is a convergence of technology, method and information. Sophisticated new instruments are being developed, allowing engineers to delve deeper into materials. Experimental approaches are maturing as some researchers dedicate their work to refining processes. And computational science and data analytics are speeding everything that's observed and learned, present and past, to shape new understanding.

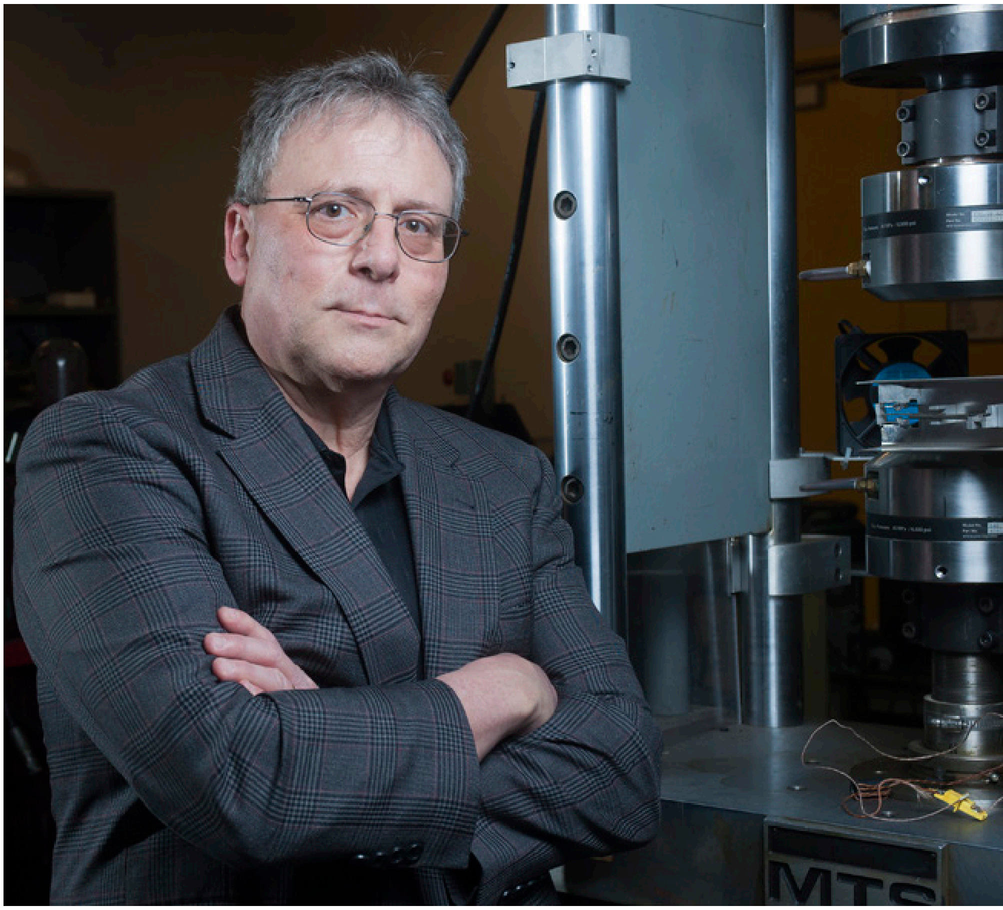
"By 2030, a lot of our initial thinking about what materials design looks like will have changed," says Dave McDowell, a professor with dual appointments in mechanical engineering and MSE. "It'll be replaced by autonomous, smart systems that have artificial intelligence engines working in the background. These systems will incorporate experimental data, simulation and expert knowledge, all to reduce uncertainty."

McDowell has been at this for 37 years inside Georgia Tech's College of Engineering. In the early days, he conducted stepping-stone experiments like everyone else. But in the 1990s, he saw the potential of using computer science to extract more insight out of those experiments.

"And then came what I call the 'democratization' of quantum mechanics," he says. How subatomic particles moved and interacted could now be better understood by a wider range of investigators, opening up a trove of new principles and theories for MSE researchers to explore. The discipline was morphing into something more predictive, thanks to a fusion of experiments, computation and data science.

"There's probably 10 universities in the U.S. today best known for excelling in this convergence," McDowell says, "and we're one of them."

One superstar in the computational field came to the College of Engineering in 2017. His name is Rampi Ramprasad, a GRA Eminent Scholar who melds quantum mechanics with computer models to propose hypothetical new substances. The approach allows him to evaluate hundreds of potential materials, the most promising of which can be chosen for further experimentation.

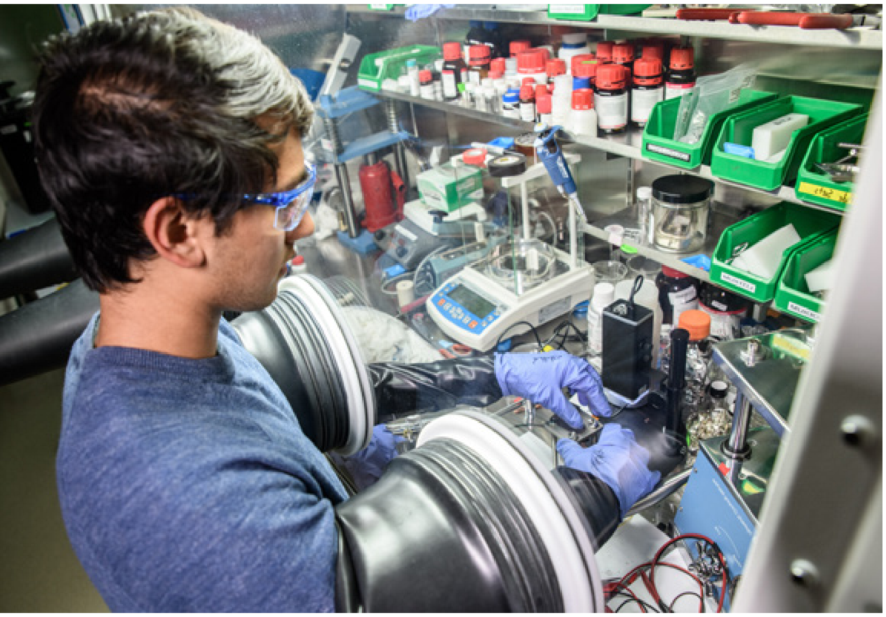


ME and MSE Professor Dave McDowell. CHRISTOPHER MOORE.

By leveraging computing and data science, Ramprasad develops new tools for researchers to create or modify materials. The beauty of such tools is that they help engineers imagine what could be — or, in the case of Matt McDowell, to see what really is.

Matt McDowell is an assistant professor in MSE and mechanical engineering and, so it happens, the son of Dave McDowell. His specialty is *in situ* experimentation, which allows him to witness what happens to a material — all the way down to the atomic level — as different kinds of stimuli are applied.

The refinement of lithium-ion batteries over the past decade has ushered in a new era of charging capacity. The next step is to develop new materials that can make them last longer — no small feat, as evidenced by McDowell's work.


ROB FELT

Batteries are a big part of McDowell's work. The refinement of lithium-ion batteries over the past decade has ushered in a new era of charging capacity. The next step is to develop new materials that can make them last longer — no small feat, as evidenced by McDowell's work.

In one set of experiments, he designs a battery that allows it to be inserted into a synchrotron, a massive circular machine with a diameter bigger than a football field. "We bombard the battery with X-rays and get a three-dimensional view of what's happening to the material inside that battery, over time," McDowell says.

Though less than a centimeter in width, that view of the battery is considered large scale, and his experiment yields so many terabytes of data that a single hard drive can't hold it all. Yet for McDowell, that's only half a look. Using different instruments, he also studies what happens when he assails the same material with electrons. The product of that effort is a 2D video of what's occurring at the atomic level as the battery charges and discharges.

"Developing new materials can either improve the batteries we have now or bring an entirely new energy storage system," McDowell says. "Our lab is using *in situ* experiments for both purposes." McDowell thinks we're only a few years away from a battery that lasts 20% longer, thanks to new materials inside existing cells. Beyond that, an entirely new platform like solid-state batteries could bring 50% longer storage.

Such a battery would change the world, and not just because you'd need to charge your phone less often. It would make electric vehicles far more commonplace

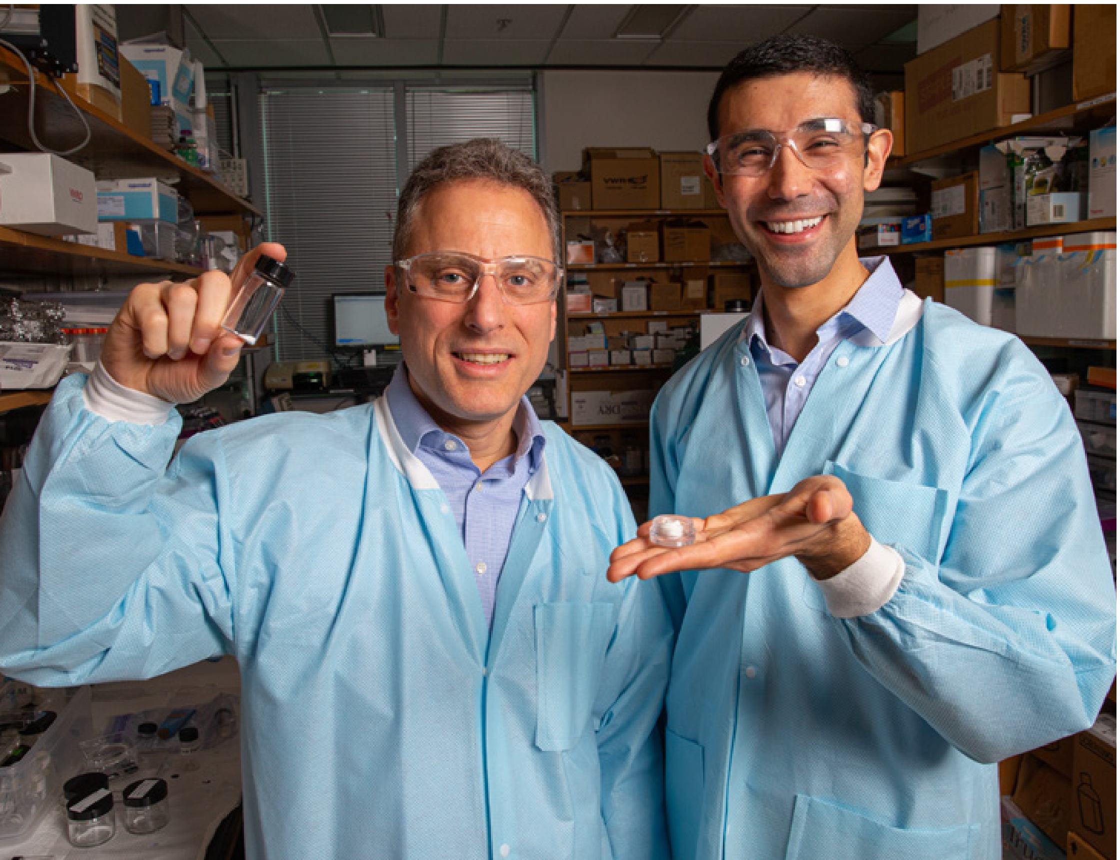
MSE Assistant Professor Matt McDowell. ROB FELT.

because they'd travel much further. Beyond that: In your lifetime, you just might be able board an aircraft that has numerous battery-powered engines, rather than a few gas-turbine ones.

Pushing the engineering envelope

As MSE research gains momentum, new answers to problems enter the picture, and the College of Engineering is doing its part. There's Mark Losego assistant professor of MSE, and Shannon Yee, associate professor of mechanical engineering; together, they've developed an alternative to pressure-treated wood. By employing the atomic-layer deposition methods used to manufacture semiconductors, the two have developed a way to permeate the cells of wood with a few atomic layers of material. This makes the wood more water-resistant than the pressure-treated variety and brings the added benefit of reducing heat loss in homes.

ROB FELT



"More smart people attacking major problems could speed things up. We have to make sure the field remains interesting for students who choose to further their education."

Elsa Reichmanis

There's Craig Green (Ph.D. ME, '12), the CTO of Carbice, a Georgia Tech startup. The company has engineered a kind of "wonder tape" that, when integrated into electronics, dissipates heat, a huge problem as electronics become more powerful. Forged from carbon nanotubes, the thermal material is already being used in space satellites.

There's Mark Prausnitz, Regents Professor in the School of Chemical and Biomolecular Engineering and a pioneer in microneedle technology. His latest invention is called STAR particles. The materials hold infinitesimally small needles that contain medication, and when rubbed into the skin as a cream, the particles promise to improve treatment of skin diseases.

And there's Elsa Reichmanis. An accomplished researcher from Bell Labs and a professor in the School of Chemical and Biomolecular Engineering — her work, among other things, led to new families of lithographic materials that advanced semiconductor design. She has a rare vantage point from which to view the future.

Last year, Reichmanis joined some of the nation's most accomplished materials experts on a National Academies of Science, Engineering, and Medicine super-committee to study what the decade ahead will bring. It was an exhaustive effort, delving into metals and alloys, ceramics and composites, two-dimensional materials and meta-elements.

"A lot of new things will be coming out," Reichmanis says. "I believe we'll have truly biodegradable packaging materials. We're not going to be throwing out all this plastic. I think we're going to have manufacturing processes where we're not emitting the amount of greenhouse gases we are now. We'll have even more renewable energy sources — there are tons of opportunities there."

What will it take to get there? Reichmanis maintains that the best investment is in efforts that assure a growth of mindpower.

"More smart people attacking major problems could speed things up," she says. "We have to make sure the field remains interesting for students who choose to further their education. That requires changing how we present the information to students, not just so they understand it, but so they say, 'Aha! This is really interesting. I want to be doing this.'"

Which is to say, the pull of complexity and the push of acceleration demand a greater diversity of innovators and ideas. If the future is a contest of minds versus matter, it's essential that the minds win. ◂

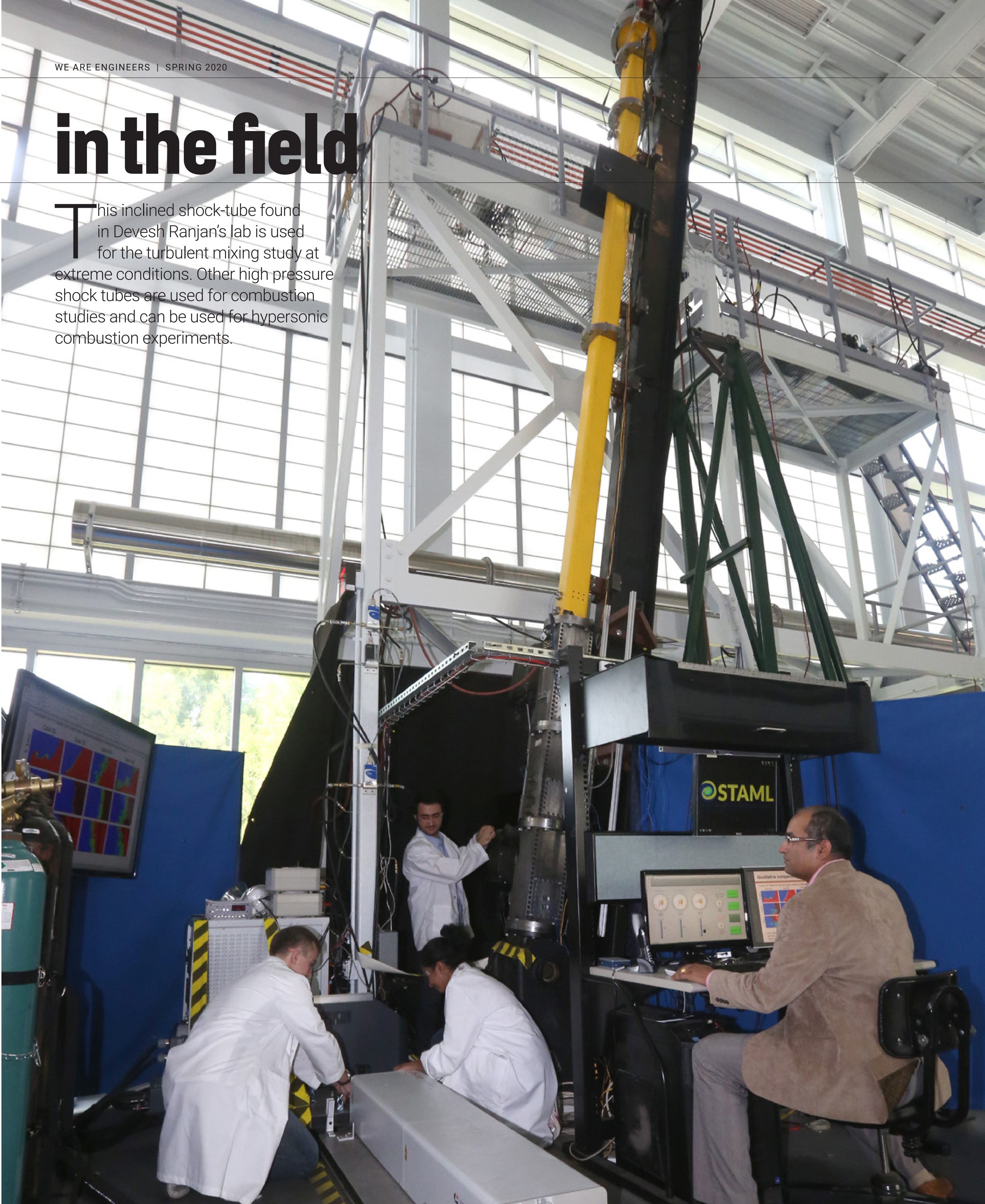
Opposite page top: Shannon Yee and Mark Losego demonstrate the effectiveness of their alternative to pressure-treated lumber. ALLISON CARTER.

Opposite page bottom: Mark Prausnitz and postdoctoral scholar Andrew Tadros with the STAR particles. CANDLER HOBBS.

This page: Craig Green, CTO of Carbice. CRAIG BROMLEY.

in the field

This inclined shock-tube found in Devesh Ranjan's lab is used for the turbulent mixing study at extreme conditions. Other high pressure shock tubes are used for combustion studies and can be used for hypersonic combustion experiments.



In His Own Words

Bao Nguyen reflects on his passion for cybersecurity and why he chose to take his education 'online'

Back in 2015, I was a victim of identity theft. Somebody stole my social security number, my name, my address and my phone number. They opened up bank accounts and credit card accounts. At that time, I got scared, because I didn't know what I was supposed to do, and I didn't know if I would get any of that back.

That experience got me thinking. How do I keep myself safe? How do I keep this from happening again? It made me look more deeply into cybersecurity. I'm currently an IT support professional with the School of Electrical and Computer Engineering, and ,occasionally, I deal with some cybersecurity issues in my work. When I learned about Georgia Tech's Online Master of Science in Cybersecurity (OMS Cybersecurity), I became very interested in the opportunity to deepen my knowledge in this field.

I started the degree program in the fall of 2019. Out of the three concentrations offered — energy systems, policy and information security — I chose information security because it allows me to dig into the software and coding side. I love to try to find the chinks in the armor, the loopholes that hackers might try to take advantage of.

It's been a while since I was in school; I graduated from Georgia Tech back in 2004 with a bachelor's degree in computer science, a minor in chemical engineering and an IT management certificate. I'm so happy to be back as both staff and student now, and the online program is especially useful because now I have a job, a family and a busy life.

The online program offers me some incredible benefits that even in-person classes couldn't provide. I get to work with people from all over the world. I have friends on the west coast, in Asia, in South Africa, and there are so many people of all ages taking the same classes. Online programs like OMS Cybersecurity are going to continue to explode in popularity. They make the incredible resources of Georgia Tech accessible to so many different kinds of people. I have learned so much from my fellow students already, and I can't wait to see what we each do with this new knowledge. For me, I think this master's degree will mark my transition into a more cybersecurity-focused career path, and I am very interested in seeing where that takes me in the future.

"ONLINE PROGRAMS LIKE OMS CYBERSECURITY ARE GOING TO CONTINUE TO EXPLODE IN POPULARITY. THEY MAKE THE INCREDIBLE RESOURCES OF GEORGIA TECH ACCESSIBLE TO SO MANY DIFFERENT KINDS OF PEOPLE."

Bao Nguyen

In the coming decades, we are going to see more cybersecurity challenges due in part to greater connectivity. Everyone has these smart devices that are integrated into their phones and homes: everything from a vacuum cleaner to a thermostat. If somebody can hack my phone, they can take control of about 50 devices in my house right now. So many smarter technologies are coming out, and many people are going to be connected to hundreds of devices. If a hacker can hack 10,000 phones and raise the temperature in each house by one degree, that's 10,000 houses with a temperature raised by 1 degree — think about how much damage that is to the energy grid! Many people don't think about that, but that's what the cybersecurity of the future will need to consider.

In order to eliminate problems like cybercrime, we need better programming to close any loopholes in software programs that allow attackers to get in. But cybersecurity roles are going largely unfilled because there are not enough people with the capabilities to confront those challenges. Since I became interested in cybersecurity in 2015, the rate of unfilled positions in cybersecurity has been increasing by 50 percent every year. When I finish my master's in 2022, we might be looking at 4 million unfilled cybersecurity jobs. Jobs are out there, but they're not being filled. And when we're talking about Georgia Tech graduates filling those positions, that makes me feel a lot more secure about my future.

▶ BAO NGUYEN

BEN WRIGHT

Engineering with the Earth in Mind

Sustainability requires balancing today's needs with those of future generations

Gone are the days when engineers could narrowly focus on how to solve the challenge of the given moment. As we strain the limits of our planet's natural resources, engineers in the 2020s must consider how their work will affect people and the planet, not just now, but in the decades ahead.

We asked three faculty members from the School of Civil and Environmental Engineering how they see sustainability affecting the field of engineering in the next 10 years. Here are their perspectives.*

"Engineers are the problem solvers on the front lines, trying to balance how we're consuming resources and living our lives now, and enabling future generations to meet their needs."

John Taylor • Frederick Law Olmsted Professor

Reducing energy use

We're studying what happens if people in commercial buildings are more aware of their consumption. We've found that just telling someone the number of kilowatt hours of energy they are consuming doesn't cause a statistically significant change. But if we create a peer network group of coworkers who can actually see each other's energy use, people significantly reduce their consumption.

By 2030, I think we'll see broader implementation of cyber-physical systems, where sensors monitor what's happening within a building and can act to optimize energy consumption. For example, if it's the end of the day at an office building, the system can notify people to go to a certain area to work, and turn off the lights and HVAC in areas that are less occupied or unoccupied.

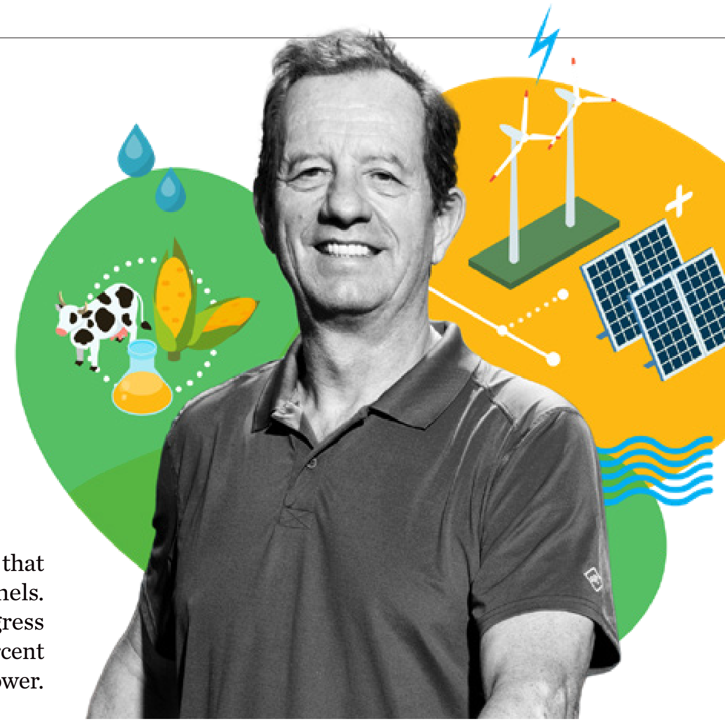
Smart cities

An analyst's report in September 2019 said we can expect 500 Smart City Digital Twins around the world by 2025. (Smart City Digital Twins are computer models that replicate a city's infrastructure; they're used to plan and manage systems. The concept originated in Dr. Taylor's lab at Georgia Tech.) Right now, some smart cities have digital twins of a single system — storm drainage, energy consumption or transportation. The important thing is to figure out how these single systems can work together to truly enhance the sustainability, resilience and livability of cities.

People assume that smart cities are sustainable, but I don't think we can assume that as a city gets smarter it will be more sustainable. I think it's going to take conscious action. As we develop smart solutions, we have to be sure we are also working toward sustainability goals. If you're narrowly focused on one goal or the other — coming up with a smart, innovative solution or being sustainable — you might miss the optimal opportunity, which is the intersection of the two.

"All engineers will be trained to be what we'll call 'good engineers.' We won't need to call them 'sustainable engineers.' We won't even talk about sustainability. It'll just become part of the culture."

John Crittenden • Director, Brook Byers Institute for Sustainable Systems, Hightower Chair and Georgia Research Alliance Eminent Scholar in environmental technologies



The gigaton problem

For years, engineering research has focused on nanotechnology. But when we talk about sustainability, we're looking at gigaton (one billion tons) issues that need gigatechnology solutions. The world economy uses about 84 gigatons of material — with only nine percent of that renewable — the energy equivalent of 16 gigatons of oil, and about 4,000 billion cubic meters of fresh water each year. Cities are responsible for ¾ of energy use and greenhouse gas emissions. Urban infrastructure systems are the largest systems in which we manipulate matter and energy, so redesigning our cities to be more sustainable is a great target of opportunity.

I think in the next 10 years, we're going to see significant movement towards infrastructure that uses renewable energy resources. In the United States, California is the leader on this front; they require that all new homes be built with solar panels. Outside the U.S., you can see the progress in countries like Denmark, where 70 percent of their energy needs are met by wind power.

Engineering new foods

With the growing world population, we'll need to increase the number of calories we produce. Engineers can use artificial intelligence to analyze and replicate animal-based foods using plant proteins. This is crucial, because livestock is an unsustainable food source. It uses about 30 percent of the world's ice-free land mass, produces about 14 percent of the greenhouse gas emissions and requires large amounts of water and feed.

"As engineers, we have a responsibility to think about how our work is going to influence people and the environment."

Emily Grubert • Assistant professor, civil and environmental engineering

Infrastructure systems

We're recognizing the effects of the power system and transportation system on climate change, and that's motivating a transition toward more sustainable systems. In energy, we're likely to see simultaneous industrialization and de-industrialization — the shutdown of fossil-fuel infrastructure and the building of non-fossil-fuel infrastructure.

In some cases, we're going to see changes to existing infrastructure, particularly in the operation of things like transmission lines or hydroelectric dams.

All of these are socio-technical systems, and as we make these transitions, the impact will be huge, from the international level all the way down to the local level.

Culture shift

Engineers have long recognized that we have an obligation to make sure that our projects are safe. Most engineers would push back if a client asked them to do something unsafe. I think sustainability is a different form of safety, just on a broader, societal scale.

We're really starting to understand that we work within social systems, that we work for people and we work to protect the public.

▶ DORI KLEBER

**Responses have been edited for length and clarity.*

10 TO END

10 Questions with Sophia Velastegui

Businesses across the world are quickly being shaped and redefined by new applications in artificial intelligence (AI). Sophia Velastegui (B.S., ME) is playing an integral role in the development of AI across different business units at Microsoft. She is currently serving as the chief technology officer for operation applications at Microsoft. Velastegui has received numerous awards and accolades for her contributions to the technology industry, including being recognized by Business Insider as one of the 'Most Powerful Female Engineers in the World' for her work in advanced technology at Google and then again for her work in AI at Microsoft. We sat down and asked her a few questions about her experience as an engineer and just what the future decade holds for AI.

1 ▸ **Where are you from?** I was born in South Korea but came to New York City when I was one. I consider myself a New Yorker. **2** ▸ **What is your degree from Tech? Any other engineering degrees we should know about?** I earned my B.S. in Mechanical Engineering from Georgia Tech. I then went on to UC Berkeley and earned my M.S. in Mechanical Engineering, specializing in Materials. After that, I completed executive education programs at Harvard Business School and Stanford Law. **3** ▸ **What is your current job at Microsoft?** Chief Technology Officer in Operation Applications. **4** ▸ **What's a day in the life like for you working for a big tech company?** No two days are the same. I work with amazing people and customers to solve challenging problems leveraging artificial intelligence and other emerging technology. I am fortunate to work with brilliant people and customers regularly. I love how technology can be leveraged in food services to travel to healthcare. **5** ▸ **In the coming decade, where do you see AI heading?** There will be a tech intensity in adoption and application across the board in every industry. Any degree from Georgia Tech will position you well to take advantage of business opportunities in AI. **6** ▸ **What do the '20s hold for large technology companies like Microsoft?** Microsoft's Business Application Group that I am part of will be how people interact with their data in the cloud. We are redefining and augmenting how businesses are run. **7** ▸ **How has your engineering degree helped you in your career at Microsoft?** Engineering teaches you to solve complex problems, and you learn to break down systems into components. Engineering is an effort of grit, passion and perseverance for a long-term goal. I have applied these techniques and processes to my career development and advancement. **8** ▸ **At Tech, we are all about innovation. How are you innovative at Microsoft?** We are in the golden age of AI. My job determines new usage of AI into various business units and products that open new capabilities and introduces new business models. New products are being introduced based on AI as we speak, from Dynamics 365 Customer Insight to Fraud Protection. **9** ▸ **Where do you see yourself in five years?** I'd like to continue to solve challenging global problems but, beyond that, solve more significant audacious problems with more substantial impact. **10** ▸ **What advice do you have for young engineers, especially women engineers, looking to work in big tech?** Take intentional risks. If you meet 50 percent of the job requirements, go for it. You will be rejected, but if you are not failing regularly, you are not trying hard enough. Be bold, but be strategic. When I decided to go from the semiconductor field to the leading consumer in electronics, Apple, many stated that it couldn't be done. But I tried and got feedback, pivoted, and then I landed at Apple as a product manager in three years. Also, since I was strategic and intentional, I was able to do so while increasing in responsibility. It's also important to learn to get comfortable and excel at negotiation. Take negotiating classes or, at a minimum, read about it. My favorite is "Never Split the Difference" by Chris Voss. Conversation and life are about negotiation. Once you master it, you will be more likely to be positioned for success and better compensated. Finally, learn to be comfortable with data regardless of your degree or background. It could be taking classes or volunteering for projects working with data scientists.

Do you have a Georgia Tech engineer working at your company? We'd love to hear from them. Email us at editor@coe.gatech.edu.

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parting shot

Lithograph of an aerial view of the Georgia Tech campus, circa 1920. Reportedly, the drawing was done from a hot air balloon over North Avenue.