# 2020 ANNUAL REPORT

Georgia Tech Research Institute

CREATING THE NEXT®

**James Hudgens**
**Director,**
**Georgia Tech**
**Research Institute**
**Senior Vice President,**
**Georgia Institute**
**of Technology**

## Message From the Director

I am honored to welcome you to the Georgia Tech Research Institute's (GTRI) 2020 Annual Report. The past year posed a unique set of challenges for all communities. GTRI prides itself on being the innovation hub for award-winning and nationally renowned researchers, engineers, and industry professionals who are dedicated to bringing innovative solutions to some of the world's most complex challenges. Perhaps this year, more than ever, the world was in need of the expertise and ingenuity of those at GTRI.

GTRI has experience in solving some of the nation's toughest problems as the applied research unit of the Georgia Institute of Technology (Georgia Tech), and as a Department of Defense (DoD) University Affiliated Research Center (UARC). During fiscal year 2020 (FY20), GTRI continued to innovate technical solutions for national security and government applications, state and regional economic development, and the overall welfare of humanity. While maintaining normal operations, GTRI also pivoted attention to Covid-19 related research. GTRI employees quickly responded by creating a low-cost ventilator, portable disinfection chambers, and essential personal protective equipment. We also supported the State of Georgia's Covid-19 response by implementing a statewide data management capability, stabilizing the supply chain, and developing a new Georgia-based test implemented at Georgia Tech. GTRI embraced a virtual platform for our science, technology, engineering, and mathematics (STEM) outreach, continuing to support students and teachers closer to our home.

Throughout this report, you will read about our technical achievements and their impact on various sectors. The technical achievements represent what we do, but, perhaps, more important are the root of GTRI's success — our incredible research faculty and staff who displayed adaptability in the midst of crisis. As GTRI navigated Covid-19, taking health precautions to safeguard our community, we continued to perform sponsored research. Additionally, GTRI invested $13 million into our internal research and development (IRAD) portfolio, funding over 230 projects. It is from these internal and sponsored projects that GTRI has been able to support the Centers for Disease Control and Prevention (CDC) through expert data analysis for their Covid-19 information dashboards, test our intelligent cutting system at a local poultry plant to assist the line workers, serve our military sponsors with open architecture devices, and much more.

I invite you to read through this report, which gives you a glimpse into our accomplishments, research investments, and outreach programs, and hopefully encourages you to engage with us on future endeavors.

## GTRI Leadership

GTRI's renowned, award-winning team constantly pushes the limits to discover "what's next." GTRI continues to grow, now exceeding 2,700 employees across our 18 locations. Our employees not only bring their expertise to innovating the next solutions at GTRI, but they also influence their surrounding communities, serving through various organizations, receiving awards, and authoring books. As members of the Georgia Tech community, our employees also have an impact on campus, teaching classes and leading student research through vertically integrated projects (VIPs).

**James J. Hudgens**
Director, GTRI
Senior Vice President,
Georgia Institute of Technology

**Don Davis**
Deputy Director,
Electronics, Optics,
and Systems

**Wen Masters**
Deputy Director,
Information and
Cyber Sciences

**Bill Melvin**
Deputy Director,
Sensors and
Intelligent Systems

**Mark Whorton**
Deputy Director,
Chief Technology
Officer

**Keith McBride**
Chief of Staff

**Jeff Hallman**
Deputy Director,
GTRI Operations Officer
(Interim)

**Kim Toatley**
Deputy Director,
Finance and Research
Administration

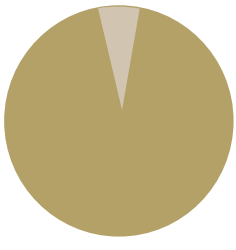
**Raj Vuchatu**
Deputy Director,
GTRI Information
Officer

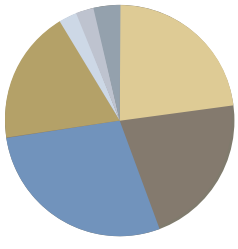
**Romy Smith**
Chief Counsel

## Financial Statement

**575 MILLION**
RESEARCH REVENUES

**535 Million Federal**
**40 Million Non-federal**





**RESEARCH BREAKDOWN BY CUSTOMER FOR FY20**

| | |
|---|---|
| Air Force | 26.24% |
| Army | 22.13% |
| Other DoD | 22.32% |
| Navy | 20.24% |
| State, Local Gov't. | 3.74% |
| Private | 3.33% |
| Other Non-DoD Federal Agencies | 2.00% |

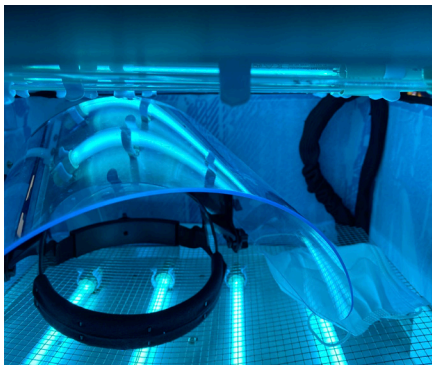
| GTRI BY THE NUMBERS | GA TECH FY20 | GTRI FY20 |
|---|---|---|
| Sponsored Research Awards: | $1.0B | $663M |
| Revenue Earned: | $1.1B | $535M |
| Economic Impact to State: | $3.8B | $1.5B |
| Total Employees: | 8,888 | 2,753 |

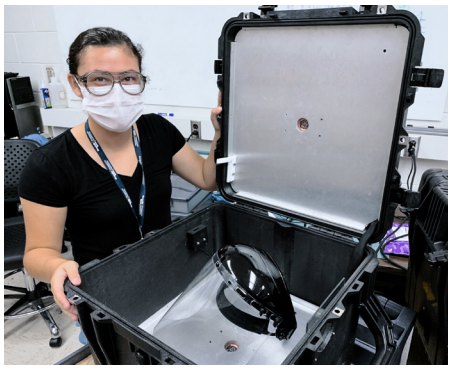
Generating high-paying jobs. Keeping USG graduates in Georgia.
Driving economic growth in Georgia.


## Simple, Low-Cost Ventilator Builds on Available Resuscitation Bags

During the Covid-19 pandemic, a need arose for low-cost, life-saving equipment, so an international team of researchers designed a ventilator that can be produced from inexpensive metal stock and plastic gearing. The device, which was based on the resuscitation bags that are carried in ambulances and widely available in hospitals, was built and tested at Georgia Tech.

GTRI has experience with bringing concepts to reality. In collaboration with Emory University, GTRI researchers teamed up with their Georgia Tech colleagues to support quality control and testing procedures and advised on manufacturing scale-up for the devices. The emergency ventilator, which was 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. The device can serve two patients simultaneously with separate airflows to prevent cross-contamination. Flow volumes can be controlled independently to meet the needs of each patient.





## Portable UV Disinfecting Chambers

Portable disinfection chambers that use ultraviolet (UV) light to inactivate virus particles could allow healthcare workers, emergency medical technicians, and others to quickly disinfect their personal protective equipment (PPE), including face shields and masks. In FY20, GTRI researchers built two prototype chambers to evaluate PPE disinfection using different sources of UV-C light: mercury vapor lamps and light-emitting diodes (LEDs). The goal was to make these disinfection chambers as small as possible to allow for portability.

The research team designed the chambers to provide the level of UV exposure that earlier studies had shown would inactivate the closely related SARS-CoV virus by damaging its outer shell and RNA. The researchers did not attempt to evaluate the ability of the UV light to inactivate the SARS-Cov-2 virus that causes Covid-19.

Other engineering considerations included the need for cooling the UV sources, providing consistent exposure of the PPE to UV light using reflective walls in the chambers, and protecting the mercury vapor lamps from damage during use.

## Enabling Georgia's Coronavirus Test Initiative

Gaps in the supply of coronavirus tests have propelled initiatives to fill them across the country. During FY20, Georgia Tech bioscience researchers began burning the midnight oil to produce key components for tests in the State of Georgia.

Researchers worked to support a broad initiative by the governor's office, involving multiple universities and partners, to rapidly produce and administer more tests. At least 35 volunteers at Georgia Tech, while adhering to social distancing, reoriented labs normally used for scientific discovery to facilitate larger-scale production of biochemical components.

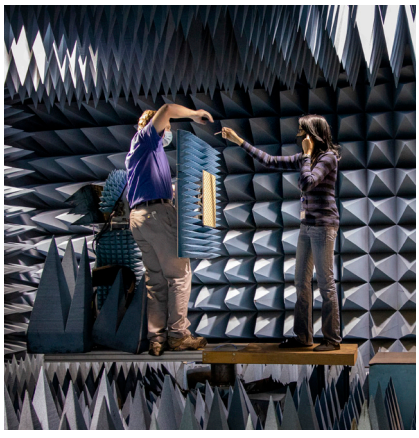
Researchers began supporting Georgia Gov. Brian Kemp's Covid-19 State Lab Surge Capacity Task Force, which is a project managed through GTRI. GTRI has also led the coordination and integration of data management across the lab surge effort.

"We are providing technical and project management of the effort, which is focused on increasing the state's ability to expand testing beyond current limitations," said Mike Shannon, GTRI's lead in the project and a principal research engineer at GTRI.

The science behind coronavirus testing is complementary to the researchers' usual work. That includes understanding proteins associated with glaucoma, figuring out how RNA and DNA evolved in the first place, or whether ribosomes — lumps of RNA and protein key to transcribing genetic code into life — may exist on exoplanets.

The group has teams that engineer the production of enzymes or other chemicals needed for reverse transcription poly-merase chain reaction (RT-PCR), a chemical reaction that amplifies the virus' genetic fingerprint, to work: two central enzymes are reverse transcriptase, which converts RNA to DNA, and Taq polymerase, which rapidly replicates DNA. Another important component is ribonuclease inhibitor, which slows coronavirus RNA decay.

The state wanted to increase current testing capacities by 3,000 more tests per day. The task force also includes teams from Augusta University Health System, Georgia State University, Emory University, University of Georgia, and the Georgia Public Health Laboratory. The task force lead is Captain Kevin Caspary, who is with the Georgia National Guard.



## Shifting the Paradigm

In FY20, GTRI researchers developed a concept for a Low-Cost Phased Array Radar (LCPAR) based on primarily commercial-off-the-shelf (COTS) hardware arranged in modular and scalable units, a software-reconfigurable and open system architecture, and a streamlined and more effective government acquisition process.

The design was intended to revolutionize the way the government does business by flexibly fitting to the diverse set of needs from program offices, enabling the rapid development and deployment of capable and cost-effective radar solutions. The COTS-based design leverages the breakneck advances in semiconductor and digital hardware seen as a result of 5G innovation. These advances have resulted in exponential performance gains while simultaneously reducing costs, power requirements, and packaging constraints. The technology will be built into a modular concept that can be easily scaled to meet varied radar requirements. In addition, the technology will use an open system architecture, with commonality designed into various components of the radar, maximizing reuse of design and minimizing non-recurring engineering – pushing schedule leftward. The design moves digitization close to the front-end aperture and employs a software-reconfigurable framework, enabling agile insertion of new software modes.

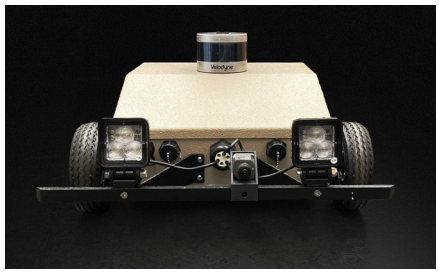
The typical government acquisition process is evolving, as GTRI offers a compelling alternative to the status quo. In the past, government program offices bought new radars, but the large, industry contractors retained proprietary ownership of their radar designs. This resulted in program offices' being locked for decades in their sustainment and modernization contracts to the original equipment manufacturer (OEM). GTRI aims to change this philosophy by offering instead to produce the prototype radar for the program office and, along with it, give the government ownership of the technical baseline. The government can then compete out however many radars it needs to industry. This process gives more control to the government and ensures they are better equipped to making sound technical decisions over the entire life cycle of the radar – rather than the right decision for the shareholders of the industry contractor with the at-the-time most compelling bid.

## A Robotic Assistant for the Marines

ARTI is a four-wheeled robot designed to perform autonomous inventory management tasks at the Marines Corps Logistics Base in Albany, Georgia. Using sensor feedback and onboard software, ARTI creates maps of warehouse interiors. Human users can then mark points of interest on those maps that ARTI can autonomously navigate while avoiding both stationary and moving obstacles.

The base places radio-frequency identification (RFID) tags on their inventory assets. ARTI has an onboard RFID tag interrogator that it uses to determine the presence of specific assets on its routes. ARTI notes the presence of the assets encountered during patrols and uploads this data to a website that can be viewed by human technicians.

When using human personnel, the Marines generally perform monthly inventory checks because it is such a pull on their resources. However, ARTI can execute inventory checks daily, with more consistency and accuracy than a human worker.



## A Low-Cost Design for a Greater Need

During March 2019, GTRI began collaborating with the Navy Manufacturing Technology Center for Excellence (ManTech) to design a low-cost, government, commercial off-the-shelf (COTS) radio capable of operation from 70MHz to 6GHz with support for multiple-input-multiple-output (MIMO) waveforms. The goal was to provide C5ISR (command, control, computers, communications, cyber, intelligence, surveillance, and reconnaissance) links among swarming unmanned aerial vehicles (UAVs). A GOTS (government off-the-shelf) solution allows the platform to be evolved to any niche needs related to C-SWaP (cost, size weight, and power) or performance. For example, a user could replace the Ethernet interface board with a mini Crypto board to handle secret data, or one could replace the front-end radio frequency card with one designed to specific performance requirements. GTRI's design also allows the sponsor to obtain ownership of rights and control of manufacturing to meet supply chain needs. During FY20, the software defined radio was successfully manufactured, integrated, and tested. Future plans include development of the security interface board to allow for classified data exchange over the radio, development of a targeted frequency RF board, and development of additional waveform capabilities.

## Robotic Integrated Pallet System

Palletization is not a simple task. Boxes need to be well-stacked without gaps to ensure they are stable and configured to allow for optimal box-to-pallet density. This is a labor-intensive and tedious process requiring ample experience.

"Every year, the United States Marine Corps, which often relies on active-duty soldiers to perform these tasks, suffers loss to personnel through injuries related to palletization," said Konrad Ahlin, GTRI research egineer. "Our team hoped to create a configurable and agile system that might one day be used to ease the burden placed on American soldiers."

The Robotic Integrated Pallet System team successfully created a system that uses two robotic arms, a concurrent action server, several custom algorithms specific to palletization, and methods generalizable to other systems that combine to autonomously construct a dense pallet load-out from a custom order form.

Furthermore, the Knowledge Driven Robotic framework the team developed provides greater flexibility, reuse, and standardization of robotic algorithms. Through extensive utilization of databases, schemas, and emerging robotics standards, the robotic arms can be adapted to multiple different uses.

## Detecting Invisible Threats

Weaponized bioaerosols that carry harmful bacteria and viruses are a serious concern for American troops on the ground. Since the Biological Warfare Convention of 1972, by law, the United States does not use biological agents in its warfare strategies. However, other countries' militaries are suspected of being prepared to do so. To detect these threats, troops have to enter the contaminated areas wearing personal protective equipment and physically collect samples to be tested in a lab. However, GTRI researchers created the Bioaerosol Collector for Areal Deployment (Bio-CAD) so that soldiers do not have to expose themselves to potentially dangerous biological agents. An additional advantage of Bio-CAD is that it significantly speeds up the detection time.

Bio-CAD is a low-SWaP (size, weight, and power) device that can be attached to an unmanned aerial vehicle (UAV), such as a drone. An operator would fly the drone into a suspicious plume, and the Bio-CAD device could collect samples from it. When plumes cannot be seen, such as at night, the Bio-CAD can detect the number of particles in the air around it to help the operator locate the potential hazard. After collecting samples from the air, the Bio-CAD's filter can be removed and tested in a lab for biological agents.

GTRI has tested the device in its bioaerosol chamber using non-hazardous organisms, and researchers are planning a field test later on. To improve the device in the future, researchers want to add a chemical collection filter to detect other kinds of microscopic threats.

## Intelligent Cutting System

People are much better than robots when it comes to performing routine labor tasks, such as picking fruit from trees, sorting parts from a bin, or deboning chicken in a poultry plant. However, robots are useful for ensuring consistency in the products that a plant produces.

If you walk into any poultry processing plant, the majority of the line workers you will encounter are engaged in some form of deboning or trimming of product with a knife. Natural variability causes each bird that is coming down the line to slightly differ from the next. A handful of fixed automation solutions currently exist, though they are no match for human deboners in terms of their ability to extract the maximum amount of yield in meat. However, poultry processing plants are chronically plagued by labor turnover; the line jobs are dull, dirty, and dangerous.

To improve deboning productivity, GTRI researchers created an intelligent cutting system for automated bird front half deboning. Using pioneering machine vision to size up each bird, followed by optimal cutting paths, the robots would work alongside people in a poultry processing plant to ensure a quality product. A limited in-plant trial was conducted in early summer 2020 at a local poultry plant. Initial results proved the system's performance was on par with that of human workers, and discussions are underway to secure a commercial partner for the technology.

## Simplifying Healthcare Information Management

Medicaid is an important healthcare benefit for 17% of Georgia's population[1], and the Department of Community Health (DCH) provides nearly more than $11 billion each year to support that need[1]. In 2018, DCH initiated a multi-year project with GTRI's Information and Communication Lab's (ICL) Trusted Interoperable Systems and Architectures Division (TISAD) to develop a new Medicaid Management Information System (MMIS) to support Medicaid providers, healthcare facilities, and Medicaid recipients in Georgia. The Medicaid Enterprise System Transformation (MEST) project involves procuring and seamlessly combining distinct modules (e.g., Medicaid claims processing, provider enrollment, pharmacy benefits, etc.) into a unified MMIS enterprise system. An important component of this strategy is the underlying technical architecture, which must provide system and data integration capabilities and services. TISAD is designing, developing, and deploying a production-ready integration platform (IP) as the central transaction processing component of MMIS. The IP will enable secure data interchanges between the disparate modules, and a variety of external agencies, business systems, and trading partners, through multiple secure environments in the Amazon Web Services (AWS) cloud. TISAD will begin integrating modules into the IP in 2021 and continue building the modular environment for DCH until late 2023 when the new MMIS system will be deployed in Georgia.

## Equipping Georgia Educators with Podcasting Knowledge

Students learn in a variety of ways, especially when it comes to STEM subjects. By using podcasts, for example, educators can make connections across disciplines, facilitate project-based learning, and help increase literacy and communication skills.

For the 2020-2021 academic year, GTRI's Explorers' Guild (EG) program, which has delivered free professional learning and classroom resources to Georgia's K-12 educators since 1999, facilitated a four-part series on podcasting — and elaborated specifically on the benefits of student-created podcasts. Despite the program's transition to a virtual format due to the Covid-19 pandemic, 58 educators attended the series, representing a 38% increase from the 2019-2020 school year.

"Assessing what students know can be challenging in virtual learning," said Leigh McCook, GTRI division chief and director of STEM@GTRI. "However, podcasts offer a way for students to show what they have learned and what skills they've mastered in argumentation, constructing explanations, evaluating evidence, and more."

Over the four sessions, attendees heard from various subject matter experts. Fred Rascoe, scholarly communication librarian and aerospace engineering liaison, and Charlie Bennett, public engagement librarian, presented on ways to communicate information and use podcasts as a resource and source of content, before providing a technical overview related to podcast production. Christy Todd, co-founder of the Fayette County Public Schools' "Community for Creativity" initiative, explored integrating podcasting in the classroom. Tyler Kinner, STEM curriculum development lead at GTRI, and Heidi Turcotte, the Center for Education Integrating Science Math and Computing (CEISMC) program director for campus and community coordination, shared podcast resources and helped educators plan podcast-based learning for their own classrooms.

The EG program continues to bring together STEM experts and educators' expertise, enabling them to share knowledge and best practices for teachers across the State of Georgia. GTRI looks forward to continuing the virtual EG program in 2021, covering a range of topics like prototyping, design, and gaming.

1 Source: Kaiser Family Foundation

## Gaining Real-World Experience in Quantum Computing

During FY20, GTRI researchers advised a team of undergraduate students to stand up a quantum computing testbed that could automatically run jobs submitted by email. The students worked to revive the quantum computing hardware that was developed by GTRI researchers, connected it to a job submission software, and then ran small quantum algorithms. The interdisciplinary team included physics, computer science, and aerospace engineering majors. After reviving the quantum computer apparatus throughout the fall of 2019, the students programmed the testbed to run small quantum algorithms. In February 2020, the project culminated in a live demonstration in which more than 30 jobs were received from 15 faculty members and students. Shortly after the demonstration, the testbed was taken offline to be used for OPTIQ, a new project under the Defense Advanced Research Projects Agency's (DARPA) ONISQ program, which aims to solve combinatorial optimization problems on quantum hardware. Three of the students continued to make substantial contributions to OPTIQ remotely throughout the spring and summer. GTRI hopes to continue student engagement in the future with a vision for building a small quantum computing testbed on campus for both students and researchers to gain hands-on experience with real quantum hardware.

## Facilitating the Growth of Undergraduate Students

The Undergraduate Research Intern Program (URIP) is organized as a technology research and development portfolio where Georgia Tech undergraduate students in engineering, hard science, and public policy are partnered with research mentors at GTRI to conduct fundamental and applied research in topics that have a direct relationship with Department of Defense (DoD) objectives. During summer 2020, GTRI hosted the annual program, providing the opportunity for 51 undergraduate students to work on one of 21 advanced research projects. In addition to the full program, GTRI also facilitated Operation Summer Scramble by coordinating with Georgia Tech's College of Engineering to identify students who had their internships canceled due to Covid-19. Operation Summer Scramble hired 37 additional students for abbreviated six-week internship opportunities.

GTRI was proud to maintain its full internship program during the pandemic's height, transferring the undergraduate internship program to an online format, while still providing regular virtual interaction with GTRI researchers. Throughout the program, students built their knowledge and assisted in projects dispersed across GTRI, including topics of machine learning, robotics, modeling and simulation, cybersecurity, space technology, radar, energy, communications, optics, materials, internet of things, and human behavior, among others. Through this program, GTRI was able to advance its research while developing the next generation.

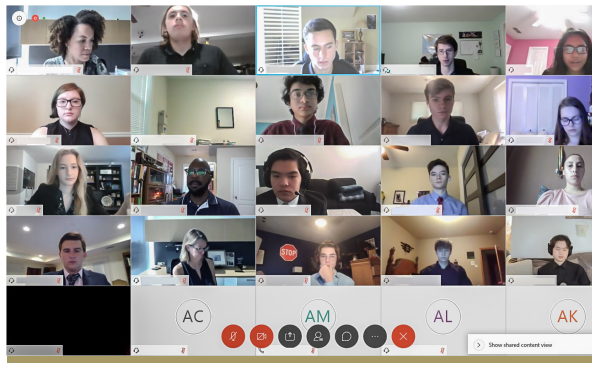
## Patuxent River STEM Outreach

In 2017, GTRI's Patuxent River Field Office began a STEM outreach program that has now presented over 96 demonstrations in 16 schools in Maryland's St. Mary's County school system. The demonstrations include a Van de Graaff generator to teach students about electricity. As the students use everyday items — tin pie plates, pom-poms, fluorescent light bulbs, and the hair on their own heads — they realize that science is engaging, practical, and something they should consider studying. These outreach efforts have involved at least 4,378 elementary and middle school students and totaled over 66 hours in the classroom.

In November 2019, the outreach team was invited to participate in the Third Annual Maryland STEM Expo, a statewide collaboration that provides inspirational, educational, and accessible programming in STEM. During the festival, GTRI researchers facilitated liquid nitrogen experiments, including freezing of marshmallows and flavored liquid cream, shrinking and expanding of balloons submerged in the liquid nitrogen, and pressurizing an empty Pringles can, causing the lid to burst off. Older students and adults were invited to dig deeper through their interactions with the exhibits, presentations, and GTRI professionals.

By attending STEM events, GTRI researchers have the opportunity to discuss their dynamic, exciting, and collaborative research work. Through these interactions, they are able to inspire students to pursue technical college degrees and STEM careers.

## Virtually Hosting High School Students




In the summer of 2020, STEM@GTRI — GTRI's educational outreach program designed to inspire, engage, and impact educators and students in the fields of STEM — embarked on its first virtual High School Internship Program. GTRI selected 55 Georgia students from an application pool of over 400 to work on a variety of virtual projects with 26 GTRI professionals across seven of the eight GTRI labs.

"I decided to hold internships in a virtual format to ensure our high school students, especially graduating seniors, were given an opportunity to acquire an experience and access mentorship so that they would be able to make decisions on a college major and school to attend, based on an authentic work experience as well as guidance from a career professional," said Erick Maxwell, GTRI senior principal engineer and STEM coordinator.

While GTRI mentors missed hosting the students in their labs, the fundamental parts of the program remained intact. Students gained technical skills, learned how to collaborate with a team, and benefited from the knowledge of experienced GTRI researchers. GTRI remains committed to facilitating internships that will cultivate new STEM leaders.

## Improving the Portable Atomic Clock

Atomic clocks may be the most accurate form of timekeeping available, but the best and most reliable atomic clocks are not portable since trapping and manipulating atoms used for the clock typically requires bulky, power-hungry equipment (e.g., large magnets, radiofrequency amplifiers, ultrahigh vacuum systems, and cooling lasers). Making the devices smaller typically involves compromising the clock's coherence for increased reliability in the field.

Sponsored by the Office of Naval Research (ONR), GTRI researchers took on the challenge of creating the first compact permanent-magnet-based Penning ion (PERMION) trap that would be compatible with laser cooling of atomic ions. Researchers designed and created a Penning ion trap a little larger than a soda can, with permanent magnets and an ultrahigh vacuum to keep beryllium (clock species) and calcium (coolant species) ions in place and protected from environmental influences. The Penning trap also featured laser cooling. The project lasted three years, and in FY20, GTRI researchers published a research paper in *Physical Review A* and obtained their first clock measurements in June 2020.

GTRI's portable atomic clock design has the potential to run on its own for more than 200 hours without slipping by a nanosecond, and the PERMION team has made the first steps toward realizing this fundamental limit. As a result of their success, GTRI researchers were awarded another project with the ONR, in which they will attempt to upgrade the clock species and simplify the laser requirements.

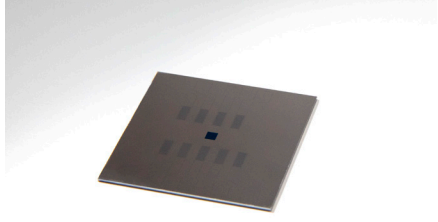
## Developing Covid-19 Information Dashboards

When the Covid-19 pandemic ushered in an overwhelming quantity of data, GTRI researchers helped develop dashboards at the Centers for Disease Control and Prevention (CDC) that sort public health data in a productive manner.

The Covid-19 analytics project was established in March 2020 as the team partnered with the CDC to provide rapid, innovative data science solutions to help CDC scientists and the public understand the pandemic trends and patterns. Specifically, they developed methods to analyze and visualize novel data sources, including mobility, news, and serology data.

The team produced data pipelines and visualizations for CDC's public dashboards on mobility and serology, which have accumulated nearly one million combined views. The public can use these tools to understand the data in their local area, and policymakers can apply the data to understand the impact of government orders on human mobility and epidemiologic data.

The team published two reports in the CDC's renowned *Morbidity and Mortality Weekly Report*. Additionally, the work has been presented at CDC Data Visualization Day and had proposals accepted to the CDC's Laboratory Science Symposium.



## Advancing DNA-Based Archival Data Storage

The Intelligence Advanced Research Projects Activity's (IARPA) Molecular Information Storage (MIST) program awarded a multi-phase contract worth up to $25 million to develop scalable DNA-based molecular storage techniques.

The Scalable Molecular Archival Software and Hardware (SMASH) project resulted from a proposal prepared by GTRI, San Francisco-based Twist Bioscience, San Diego-based Roswell Biotechnologies, and the University of Washington in collaboration with Microsoft. The goal of the project, which GTRI is leading, is to use DNA as the basis for deployable storage technologies that can eventually scale into the exabyte regime and beyond with reduced physical footprint, power, and cost requirements relative to conventional storage technologies.

Technology for encoding and decoding DNA works at small scales today, but to be useful for commercial archival purposes, researchers will have to scale up the production of synthetic DNA, reliably connect it to established computing systems, and improve the speed of the data writing and reading process. While DNA data storage is a relatively new idea, it is unlikely to become obsolete, since people will always have the need and the technology to sequence DNA. Investments in this area also feed into and benefit from other important biomedical research goals, since improvements in cost and speed of DNA synthesis and sequencing also enable faster pathogen detection and treatment discovery. Researchers hope to to encode and decode terabytes of data at costs and rates over 100 times more effective than current technologies.

## Data Enabled Automation

Preclinical studies have shown that treatment using adult human Mesenchymal Stromal Cells (hMSC) — a type of stem cell — offers promising results for many conditions, including vascular, liver, orofacial, autoimmune, and neurodegenerative diseases. These cells can be collected from different sources, such as bone marrow, umbilical cord, and adipose. Further cell-expansion using hollow-fiber bioreactor systems is necessary to produce large enough hMSC batches for clinical applications. During the cell-expansion process, however, improper concentrations of glucose and lactate can inhibit cell glycolysis — the process by which cells break down glucose for energy that is vital for cell growth. Skilled human operators can monitor and control nutrient levels, but their interventions may cause variability and lead to slow feedback control update rates. To address this problem and explore ways to automate cell reproduction, GTRI researchers began modeling a hollow-fiber bioreactor system to study hMSC expansion. Their model and controller were designed to be scaled up to any number of nutrients and nutrient flows, as well as any type of exponential growth. If successful, their project can help future research, including a study at Duke University on the effects of hMSC collected from umbilical cord for treating autism spectrum disorders in children.

## On Mission to Track Space Objects

On March 26, 2020, many watched via livestream as the U.S. Space Force launched its first satellites into space. Aboard the ULA Atlas V rocket was a small satellite — the Orbital Calibration (OrCa) mission, which was designed, built, and tested by Georgia Tech professor Brian Gunter, his students from the Space Systems Design Lab, and a team of GTRI researchers led by Christ Valenta, senior research engineer. The entire development process took a little more than six weeks.

Sponsored by the Air Force Research Lab's Space Vehicles Directorate, OrCa was intended to provide optical calibration capabilities that will improve the tracking and identification of resident space objects (RSOs) — orbiting objects that include natural and synthetic objects, such as satellites or orbital debris.

OrCa was launched as a rideshare together with the Advanced Extremely High Frequency (AEHF)-6 mission — the final satellite in the AEHF constellation. While most satellites are in low-Earth orbit below 1,000 kilometers, OrCa will be in a geosynchronous transfer orbit (GTO) — a very elliptical orbit that extends out beyond 35,000 kilometers. With its different colored panels and reinforced seams, OrCa resembles a simple box, but its unique combination of spectrally calibrated surfaces will help researchers perform experiments from Earth.

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