Georgia Tech Research Institute

2018

ANNUAL REPORT


250 FOURTEENTH STREET


TECH

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WELCOME
FROM THE DIRECTOR

I am honored to welcome and invite you to read the **Georgia Tech Research Institute's (GTRI)** 2018 Annual Report. GTRI's mission is to solve the nation's most complex problems through innovative and sponsor-focused research and education. Our "what's next" perspective remains the driving force behind the groundbreaking technology, applied research, and advanced prototyping systems that we develop.

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), we strive to provide breakthrough technical innovations for national security and government applications, state and regional economic development, and the overall welfare of humankind. The spirit of our organization can be captured in a single sentence: At GTRI, we prototype the future.

Throughout this report, you will read about our technical achievements, but none of these would be possible without our incredible staff of research faculty and support units. Although not explicitly called out, you will experience the realization that we are a collaborative community of researchers and staff, working collectively in the best interests of our organization and our sponsors to provide innovative advances. We are committed to personal and professional growth, where we invest in our employees and offer a work environment that nurtures and fosters new ideas, allowing creativity to be realized not only on paper, but also in fielded solutions. Our culture is one that encompasses transparency, respect, teamwork, innovation, impact, and community. Our work has a significant impact by making a difference for the warfighter, the community, the state, and the world.

ANNUAL ACCOMPLISHMENTS

Some of the accomplishments described in this report include:

- Partnership with the Defense Advanced Research Projects Agency (DARPA) to create and execute a **service academy swarm challenge**, in which students from the U.S. Air Force Academy, U.S. Military Academy, and U.S. Naval Academy pitted swarms of 25 unmanned aerial vehicles against each other in a "capture the flag" game to help build tactics, techniques, and autonomy for future combat operations.
- Development of **agricultural robots** for the State of Georgia to better monitor the wellness of poultry and to receive earlier and more accurate warnings of unhealthy crop conditions.
- Initiation, with Georgia Tech's School of Electrical and Computer Engineering, of a new program to develop repeatable, scalable methods for **attribution of cyber-attacks** before, during, and after their occurrence.
- Execution of an initiative for the F-35 Joint Program Office to collect, catalog, and analyze large quantities of **F-35 flight test and simulator data** to support accreditation of the F-35 Joint Simulation Environment (JSE) for operational test and evaluation.
- Development of a **new generation of atomic magnetometers** based on clouds of rubidium atoms that will be able to separate miniscule magnetic fields of interest from those created by the Earth and other sources.
- Creation of **a multi-source anticipatory intelligence** capability based on deep-learning techniques to analyze real-world events from open source data feeds to computationally forecast future social behavior.
- Development of a **real-time airborne bathymetric LIDAR system** that provides coastal zone reconnaissance, surveying, and detection while meeting tight constraints for size, weight, and power.
- Development of a **proof-of-concept health data analytics platform** for the U.S. Department of Veterans Affairs and Veterans Health Administration to support their long-term vision for interoperability and advanced functionality for future clinical and operational needs.

FUTURE DEVELOPMENTS

As demand from the DoD and other sponsors continues to grow, we have taken steps to ensure that we continue to deliver the innovative, high-quality research that our sponsors have come to expect. In 2017, we completed the purchase of a 52-acre, 750,000-square-foot property from Lockheed Martin adjacent to our existing Cobb County Research Facility, more than doubling our research footprint in Cobb County. This property, which we will begin occupying in the spring of 2019, will house new office spaces, laboratories, large-scale prototyping facilities, and a conference center.

We made significant strides toward our occupancy in one of the new Coda towers, located in Atlanta's Tech Square, for spring 2019. At this residence, we will bring our data and information centric research activities in close proximity with the Georgia Tech College of Computing, the Institute for Data Engineering and Science (IDEaS), the Institute for Information Security & Privacy (IISP) Interdisciplinary Research Institutes (IRIs), and the industry tech incubators that are flocking to that area.

We also completed negotiations on a large, new contract with the Army — signed in January 2018 and based on our DoD UARC designation — that will be a significant enabler for sponsors who wish to work with us in the future. Finally, we created a new Project Management Support Office to standardize and professionalize our skills and tools for managing some of the larger prototyping efforts that we are developing.

With every project completed and every partnership established, we take the next best step in modernizing our armed forces and progressing our local and regional community footprint. To our research sponsors and potential sponsors, to our peers and colleagues across industry and academia, to our military and civilian leaders, and to our men and women in uniform for whom much of our work is dedicated, I hope that this year's report not only gives you a glimpse into our accomplishments, research investments, and outreach programs, but also encourages you to engage with us on future endeavors.

Lora Weiss, Ph.D.
Director (Interim), Georgia Tech Research Institute
Senior Vice President (Interim), Georgia Institute of Technology


Georgia Tech

WHO IS GTRI?

WHO IS GTRI?

GTRI is the innovation hub for the industry's award-winning, nationally renowned researchers, engineers, and industry professionals who are dedicated to solving some of the nation's most complex problems.

As the highly-regarded, applied research and development division of Georgia Tech — one of the nation's top-ranked research universities — GTRI is comprised of more than 2,000 scientists, engineers, support professionals, and students who help to solve the most difficult problems facing government and industry across the nation and around the world.

DIRECTORATES

GTRI's $449 million-per-year research program is organized into three directorates: **Electronics, Optics and Systems; Information and Cyber Sciences; and Sensors and Intelligent Systems.** Each directorate aligns with GTRI's current and forthcoming capabilities in delivering solutions in applied research and technology.

In support of those directorates, GTRI operates eight research laboratories located on Georgia Tech's main campus in midtown Atlanta, and at the Cobb County Research Facility (CCRF) north of Atlanta. In addition, GTRI serves its sponsors through 20 field offices located around the United States. GTRI is also a Department of Defense (DoD) University Affiliated Research Center (UARC).

CORE COMPETENCIES

GTRI's renowned science and engineering expertise provides a significant technological advantage to our sponsors and academic partnerships. Our unique research capabilities include:

- Analysis, Modeling and Simulation, System Engineering, and Technology Development.
- Cybersecurity, Information Communication, Command and Control, and Software Systems.
- Electromagnetic Materials, and Device Technology.
- Sensors, Weapons, Electronic Warfare, and Autonomous Systems.
- Test and Evaluation.
- Threat Systems Research and Development.

This report contains examples of GTRI's achievements in the core competency areas, as well as notable facts from the 2017-2018 fiscal years.

THE ELECTRONICS, OPTICS, AND SYSTEMS DIRECTORATE (EOSD) AND LABORATORIES

In the **Electronics, Optics, and Systems Directorate (EOSD)**, GTRI conducts applied research, development, test, and evaluation (RDT&E) in most areas of materials, devices, electronics, optics, and systems. The results of the research are applied to electronic warfare (EW), avionics, missile defense, soldier systems, health care, and related areas. Three laboratories support this research:

The Applied Systems Laboratory (ASL) conducts applied research focused on ground-based air and missile defense (GBAMD), along with rotary-wing aviation systems. Activities include hardware-in-the-loop (HWIL) and software-in-the-loop (SWIL) RDT&E, system modeling and simulation, system-of-systems and family-of-systems interoperability for integrated air and missile defense (IAMD), GBAMD fire control command and control (C2), and critical safety software development and engineering. ASL conducts applied RDT&E for several government agencies located at the U.S. Army Redstone Arsenal and the local Huntsville, Alabama area.

The Electronic Systems Laboratory (ELSYS) delivers innovative research, prototypes, and education that generates positive and lasting impacts for sponsors through various activities including aviation systems integration, EW analysis, human factors engineering, and other applied research advancements and education. ELSYS develops and executes innovative ways to ensure that deployed systems stay operable, intuitive, and relevant in fulfilling the warfighter's mission — keeping mission-critical systems technologically suitable, supportable, and affordable over their life cycle. ELSYS also conducts systems engineering research programs that provide methodologies, tools, education, and leadership to support acquisition and life cycle sustainment problems. Researchers focus on developing and executing innovative ways to ensure that systems balance both capability and affordability.

The Electro-Optical Systems Laboratory (EOSL) is a leader in electro-optical (EO) and radio frequency (RF) signal and information processing, with expertise covering system design, algorithm development, and modeling and simulation for signals across the electromagnetic spectrum. Core research competencies include sensor information processing and visualization, optimization, modeling and simulation of self-protection systems, and topographic and bathymetric light detection and ranging (LIDAR). EOSL houses high performance computing facilities, which allow the EOSL Center for Optimization to perform modeling and simulation of EW, infrared countermeasures, and self-protection techniques. EOSL also houses a unique Medical Device Test Center and provides infrastructure enhancement EW program office support to the Army.

Research Highlight

Human Factors Research Helps Accelerate Mission Planning

The key to a successful flight mission is planning — sometimes several hours of it. Georgia Tech Research Institute (GTRI) specialists in human factors and human-computer interfaces are working with U.S. Naval Air Systems Command (NAVAIR) PMA-281, Strike Planning and Execution Systems in Patuxent River, Maryland to streamline the current mission planning process and identify user interface requirements supporting multi-domain mission management in next generation naval planning capabilities.

With guidance from GTRI researchers, the project will improve the usability of the mission planning software tools, creating a more consistent and intuitive screen design that's easier to learn and more logical to follow. This effort could benefit all Department of Defense (DoD) agencies for collaborative mission planning.

"We are working with Navy and Marine Corps aviators to identify areas in mission planning where workflow can be streamlined, reducing the time required to mission plan," said Marcia Crosland, project director for GTRI's Joint Mission Planning System (JMPS) User Interface Design and Usability efforts. "Our task has been to define the user interface concepts and decision-making tools to help reduce the time required for mission planning. We've created detailed designs and specifications to direct current and future development of mission planning systems."

Mission planning needs to support the ability to collaboratively plan missions involving multiple aircraft but currently does not have that capability. The planning challenge can be quite complex, involving multiple targets, ground-based threats, different aircraft types, and a variety of weapons systems. The most complex part of the process is often done by multiple pilots using whiteboards, paper, and spreadsheets to combine relevant information, consider alternatives, and reveal complicated issues.

Information from the whiteboarding process is then entered into the software system, which produces the mission plans that go on board the aircraft. The GTRI human factors team realized that supporting these whiteboarding activities in the mission planning system could accelerate the mission planning process, and they created new designs to support this functionality.

"We are making recommendations for how the Navy can streamline the process and move it all into the digital world to eliminate the paper and whiteboard processes," said Crosland. "That will allow aircrews to plan a mission more efficiently, reducing the time required and potentially highlighting places where automated decision-making tools could be brought into the process."

She added, "We've tried to understand the tasks of the user and therefore how the workflow could be streamlined. From that, we designed user interfaces that better implement the tasks, and we developed a style guide to help the DoD software programmers who were implementing it."

At each iteration of the process, prototype interface designs were evaluated with experts. In some cases, those experts visited the GTRI team in Atlanta to review and discuss the designs.

"We took them through each of the screens to find out what is intuitive to them and what is not," Crosland said. "We did this multiple times with different user groups to make sure we had a good set of interface concepts. In this work, it's critical to involve the intended users of the system."

The GTRI team has applied lessons learned from a variety of domains — desktop and web design, and commercial and military applications. For instance, shortening the distance between buttons on a screen, reducing the number of clicks necessary for a task, consolidating screens, and providing a consistent workflow direction make a digital system easier and faster to use — whether it's a website or mission planning system.

"We want to make the system a companion for the aircrews so they consider it a partner in these critical

processes," she added. In one case, the researchers were able to consolidate nine separate screens, each with different tabs, into a single screen.

"At the root of all user interface design, whether it's web or something else, is creating a time-efficient task that is intuitive so using it takes less time, less training, and creates fewer errors," Crosland said. "If you can cut down on errors because users understand the system, it will make the system more efficient."

GTRI's Human Systems Engineering Branch (HSEB) has been in operation for more than 30 years to help improve the interaction between warfighters and the technologies they use.

"We have significant experience in understanding the domains of mission planning and mission execution, and the components that make technology easier to use," Crosland said. "We use established design standards customized for a particular format, whether it's a mobile tablet or standard computer."

In addition to Crosland, the GTRI team includes more than 20 people. The leadership component includes Tommer Ender, director of GTRI's Electronic Systems Laboratory (ELSYS); Adam McCorkle and J.D. Fassett, both associate directors in ELSYS; Debra Jones, head of ELSYS's HSEB, and C.J. Hutto, associate branch head for HSEB.

The project's analysis and design team has included Buddy Ray, Stuart Michelson, Andrew Baranak, Vlad Pop, Liz Weldon, Chandler Price, Courtney Crooks, Chris Hale, Mike Fitzpatrick, Robert Kempf; technical advisor John Huggins; HCI graduate students Catherine Johnson, Sarah Brooks, and Rachel Chen; undergraduate students Megan Eberle and Spencer Frum; and other GTRI subject matter experts.

EOSD
Project Profiles

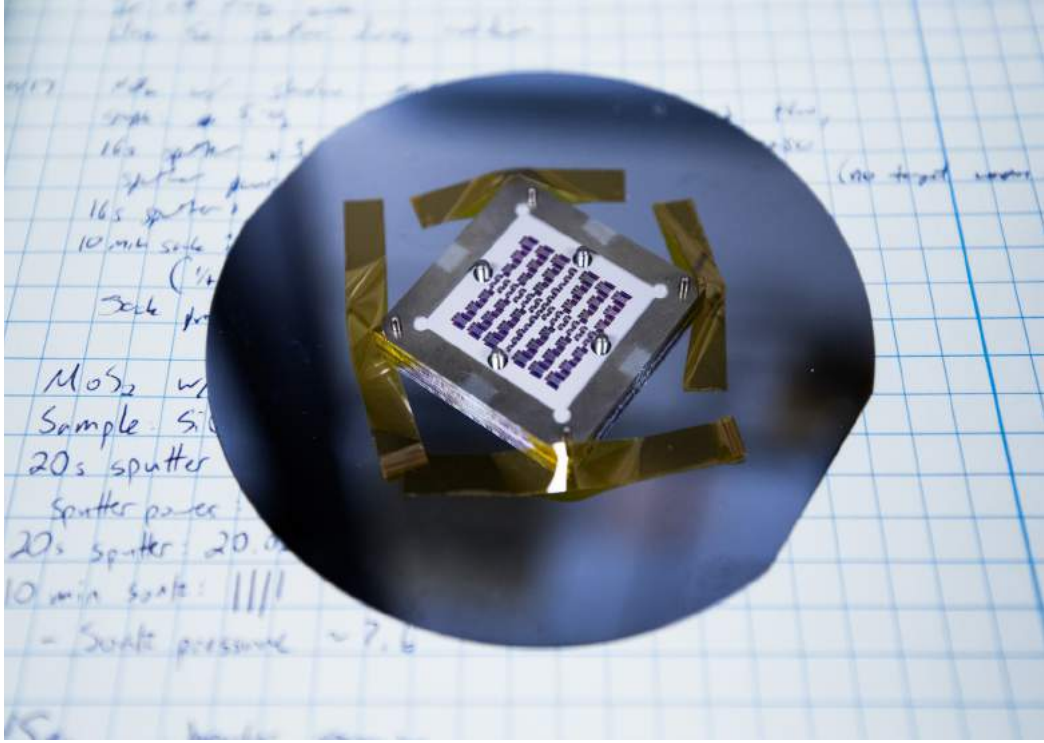
DEVELOPING HARDWARE STANDARDS FOR MILITARY AEROSPACE/GROUND VEHICLES

GTRI is leading a project to establish standards for rugged computer hardware in military aircraft and ground vehicles, including the latest generation of the F-35. The Hardware Open Systems Technology (HOST) project is part of a larger open architectures initiative at the Department of Defense to standardize hardware and software. The goal for HOST is to create an open technical reference framework for military embedded computer systems, which will foster interoperability and ultimately drive development and operations costs down. The standards will establish, for example, how connections on VPX computer cards will function, increasing the likelihood that a component such as a graphics card used in one vehicle will also function in another.

GTRI is leading a project to establish standards for rugged computer hardware in military aircraft and ground vehicles. Here, GTRI Research Engineer Joel Bernardino tests equipment built to the HOST standard.

SYNTHESIZING 2D MATERIALS FOR FLEXIBLE ELECTRONICS

Two-dimensional films made of transition metal dichalcogenides (TMDs) could provide superior properties for a future generation of low-power flexible electronic and optoelectronic devices. In collaboration with Georgia Tech academic faculty, GTRI researchers have been studying the fabrication of uniform large-area films made of molybdenum disulfide and tungsten diselenide. Using these semiconducting materials, the researchers have fabricated transistors and diodes that operate using 2D to 2D tunneling through a barrier material. Fabricated at low temperature using a modified molecular beam epitaxy (MBE) system, the materials have potential application in displays, digital electronics, sensing, energy harvesting, and other areas.

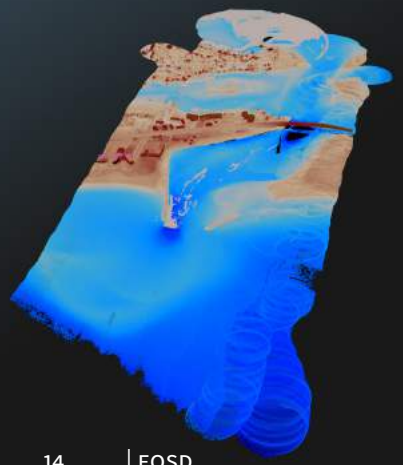


SIMULATION SUPPORTS PROGRAM TO HELP PILOTS IN DEGRADED VISUAL ENVIRONMENTS

The U.S. Army and GTRI are working together and have developed an emulator in support of the Degraded Visual Environment (DVE) Program. A degraded visual environment occurs when a helicopter landing on loose soil, such as desert terrain, stirs up dust that creates brownout conditions, which make it challenging for pilots to see obstacles on the ground. The emulation supports the development of a multi-sensor system designed to give U.S. Army helicopter pilots better situational awareness during these challenging conditions. GTRI researchers are working with the U.S. Army Aviation and Missile Research Development and Engineering Center (AMRDEC) and Program Executive Office (PEO) DVE Project Office to evaluate operation in such an environment.

NOVEL SOLAR CELLS STUDIED AFTER SPACE EXPOSURE

Solar cells developed at GTRI are undergoing evaluation after spending eight months on the exterior of the International Space Station (ISS). The experiment included a novel 3D solar cell design intended to capture sunlight from all angles, as well as cells fabricated with a low-cost copper-tin-zinc-sulfide (CTZS) materials formulation. The testing was intended to evaluate the performance of the cells and their ability to withstand the rigors of space. The cells were part of a module installed on the outside of the ISS in August 2016, brought inside the Station in May 2017, and returned to Earth in July 2017.



AIRBORNE BATHYMETIRC LIDAR SYSTEMS OFFER LOW SIZE, WEIGHT, AND POWER

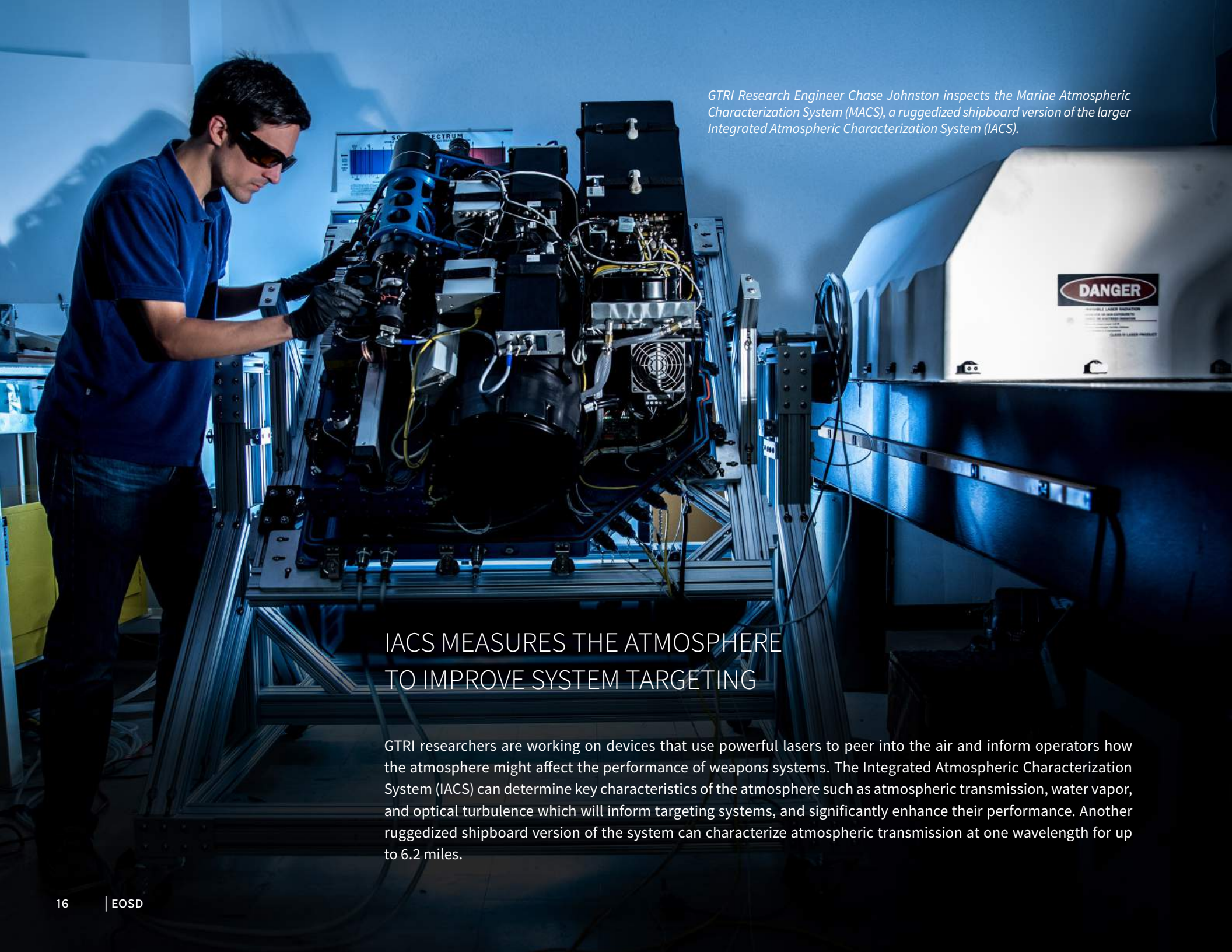
GTRI has developed a family of real-time airborne bathymetric lidar systems that provide high performance while meeting requirements for low size, weight, and power. The GTRI Bantam Real-time Dual-use Lidar (BRDL) systems feature real-time waveform processing for on-station point cloud visualization, and real-time calculation of total propagated uncertainty for on-station assessment of data accuracy. The reduced size, weight, and power of the systems is enabled by a novel receiver architecture based on a dual-zone holographic optical element and an ultra-compact, modified Ritchey-Chrétien telescope. Custom detector electronics provide high resolution, dynamic range, and sensitivity for more accurate point clouds. The BRDL family of lidars are suitable for applications ranging from coastal zone reconnaissance and surveying to sea column penetration and detection.

SOFTWARE DEVELOPERS SUPPORT MULTI-MISSION LAUNCHER

Software developers from GTRI are helping the Army integrate a new Multi-Mission Launcher (MML) designed to protect warfighters from unmanned aircraft systems, cruise missiles, mortar shells, and similar threats. Under the leadership of the Integrated Air & Missile Defense (IAMD) Project Office, researchers are adapting the Army's IAMD Battle Command System (IBCS) software to control the new launcher developed by the U.S. Army Aviation and Missile Research Development and Engineering Center (AMRDEC) for the Indirect Fire Protection Capability (IFPC) Product Office, which enhances point defense effectiveness and provides additional warfighter protection by adding the capability to fire multiple missile types from a MML under IBCS control. Among their tasks, GTRI software engineers are incorporating new software components, designing new user interface controls, and providing live-fire test and integration support. The overall program resulted from a collaboration between the Army's Program Executive Office for Missiles and Space and AMRDEC.

SET-BASED DESIGN ADVANCES NAVY STRATEGIC DECISIONS

In support of the Navy's strategic planning and budgeting processes, GTRI researchers are providing expertise in set-based design, a decision support methodology that enables leaders to understand the complex implications that resource decisions have on both the budget and capabilities. Using decision theory and computational power, the Force Level Integrated Analysis Toolset (FLINT) helps Navy leadership consider how each decision affects overall fleet strategic goals — and evaluate the risk of a potential threat response. The approach utilizes visual analytics, allowing leadership to consider the most valuable attributes of a broad range of solutions with interrelationships. The project, which builds on earlier applications of set-based techniques for platform-level decisions, is supporting the Office of the Chief of Naval Operations.



GTRI Research Engineer Chase Johnston inspects the Marine Atmospheric Characterization System (MACS), a ruggedized shipboard version of the larger Integrated Atmospheric Characterization System (IACS).

IACS MEASURES THE ATMOSPHERE TO IMPROVE SYSTEM TARGETING

GTRI researchers are working on devices that use powerful lasers to peer into the air and inform operators how the atmosphere might affect the performance of weapons systems. The Integrated Atmospheric Characterization System (IACS) can determine key characteristics of the atmosphere such as atmospheric transmission, water vapor, and optical turbulence which will inform targeting systems, and significantly enhance their performance. Another ruggedized shipboard version of the system can characterize atmospheric transmission at one wavelength for up to 6.2 miles.

ACCELERATING INNOVATION INTO THE NAVY

GTRI and the U.S. Naval Air Systems Command (NAVAIR), Naval Air Warfare Center - Aircraft Division (NAWCAD) are working together to accelerate the transfer of new technology into the Navy. The effort, known as Innovation and Modernization Patuxent River (IMPAX), can work outside standard acquisition processes to find, develop, and prototype new technology more quickly than existing processes can. IMPAX seeks out technology from sources the government doesn't usually work with, including small-sized and medium-sized businesses, matching warfighter needs with technology that may already exist — or that can be developed to meet the needs.

Rob "Radar" Winston, the GTRI principal research engineer who directs the IMPAX program, discusses how the initiative will serve the Naval Air Warfare Center - Aircraft Division.

PROJECT INVENTORIES FLUORESCING BIOMARKERS

Early and thorough detection means a lot to survival, whether it is finding a cancerous tumor just a few cells in size, or spotting a dangerous object in the dark. GTRI researchers are developing an inventory of fluorescing biomarkers that could be used in applications ranging from biomedicine to national defense. The project is identifying and sometimes modifying a broad range of commercially-available materials — including quantum dots and fluorescing proteins — that were developed primarily for biological uses.

A team of GTRI researchers led by Senior Research Scientist Allison Mercer (middle) is developing an inventory of fluorescing biomarkers that could be used in applications ranging from biomedicine to national defense.

THE INFORMATION AND CYBER SCIENCES DIRECTORATE (ICSD) AND LABORATORIES

In the **Information and Cyber Sciences Directorate (ICSD)**, GTRI conducts applied research into cyber threats and countermeasures, as well as complex computer science and information technology issues for the Department of Defense, other federal agencies, and industry sponsors.

The Cybersecurity, Information Protection, and Hardware Evaluation Research Laboratory (CIPHER) is a leader in developing the technologies that secure, defend, and respond to threats within our country's information, distribution, and network systems. CIPHER engineers and scientists develop and apply cutting-edge technologies and education in computing, network architectures, signal and protocol analysis, network forensics, custom algorithms for cyber defense and attribution, malware analysis, open source information collection and correlation, insider threat detection and mitigation, hardware and software reverse engineering, and advanced analytics. CIPHER is also a critical part of many Georgia Tech academic interdisciplinary centers, most notably the Institute for Information Security & Privacy (IISP) and the Center for Research into Novel Computing Hierarchies (CRNCH).

The Information and Communications Laboratory (ICL) conducts research that solves complex problems in areas of computer science, information technology, communications, networking, and socio-technical systems. ICL creates the next and best research innovation that supports national security through various activities including integration of health care systems, communications intelligence, interoperability and security of interconnected systems, augmented reality collaborations, geospatial decision support, smart city and Internet of Things developments, trustmarks, software modernization and integration, technology strategy and planning, development of public policy, and commercial product realization.

Research Highlight

Georgia Tech Research Institute Applies Software Engineering Expertise to Advance the State of the Art for Cyber Attribution

Barbed-wire fences, tanks, and military war plans often are associated with the term "deterrence." Yet today, such military-tough forms of cyber deterrence are increasingly needed by a range of organizations — from small mom-and-pop retailers to regional hospitals to global corporations. In response to larger and more sophisticated data breaches, private industry and government agencies alike seek a cybersecurity posture that supports the mission and protects data.

New requirements for government contractors and recent directives from the U.S. Department of Defense (DoD) — as well as related prescriptives from other federal agencies — demonstrate the need for commercial and government organizations alike to identify cyberattacks before breaches occur and determine who was responsible after they happen. This emerging science of determining who's responsible for cybercrime — a process known as attribution — plays a key role in both proactive defense and effective deterrence.

In November 2016, Georgia Tech was awarded a research contract which is now just shy of $20 million from the U.S. Department of Defense (DoD) to advance the science behind new attribution techniques. The work involves cybersecurity researchers from the Georgia Tech Research Institute (GTRI), along with academic researchers from Georgia Tech's School of Electrical and Computer Engineering (ECE).

"Attribution is critical for companies and governments alike. It enables effective risk mitigation strategies and enhanced defensive or response options for malicious cyber activity," said Michael Farrell, co-director of the Institute for Information Security & Privacy (IISP) at Georgia Tech and chief strategist of GTRI's Cybersecurity, Information Protection, and Hardware Evaluation Research Laboratory (CIPHER). "This research is developing an objective, repeatable, and scalable method for detecting activity indicating that malicious actors are preparing to strike or have commenced an operation. Attribution at scale must be focused on the network layer — across the victim's network as well as the wider Internet."

Though anonymity appears to rule on the Internet, online activities leave plenty of clues for those who know where to look. Hosts and servers make connections as part of basic operations that leave virtual fingerprints. Analysis of certain network traffic can indicate when malicious actors are establishing botnets, exercising command and control (C2), and testing data exfiltration routes. As with any crime such as robbery, there are steps that must occur prior to the actual event — reconnaissance, planning, dry runs, acquisition of tools, etc. — as well as exploitation or use of stolen goods after a heist. These have direct parallels to cyber breaches and attacks.

Without the ability to attribute attacks, assign identity, and name names, organizations have few legal, economic, or diplomatic response options. This lack of information hampers both network defense as well as business strategy development.

"Knowing who is behind cybercrime is not just of interest to law enforcement and government agencies. Commercial companies greatly benefit from attribution also since it allows them to tailor defenses and adjust business contingency operations to counter specific attackers and their motivations," Farrell said. "Attribution also allows organizations to shape a response from policy, legal, and financial perspectives and better mitigate information risk."

GTRI brings unique strengths to the program because of its extensive experience in software engineering of mission-essential applications for the DoD and security architecture review for large multi-national companies, including applying machine learning. Decades of GTRI expertise in cross-domain environments are also brought to bear in the new attribution program, which is relevant for programs that rely on both classified and unclassified data.

"We are looking at these issues from a truly inter-

Michael Farrell, chief strategist of GTRI's Cybersecurity, Information Protection, and Hardware Evaluation Research Laboratory (CIPHER), is helping develop the new science of attribution, which determines who is responsible for cyberattacks.

disciplinary, big picture viewpoint," Farrell said. "We have people working on the legal aspects, policy aspects, and financial aspects in addition to the technical and engineering aspects. And we are able to influence policy and law enforcement."

Georgia Tech's ECE plays a key role in the research on this attribution program, including Principal Investigator and Professor Manos Antonakakis, and GTRI's CIPHER Lab is a natural partner of academic units.

Recent research by the multi-disciplinary team, for example, includes new threat visualization methods and open scanning of the Internet to spot malicious changes to domain names that are intentionally similar to popular sites but used to misdirect unsuspecting web surfers.

Antonakakis and Farrell also contend that server breaches can be detected well before any malware samples are detected if network data is properly considered. The strategy takes advantage of the fact that malicious actors need to communicate with their C2 computers, creating network traffic that can be detected and analyzed. Having an earlier warning of developing malware infections could enable quicker responses and potentially reduce the impact of attacks.

Traditional defenses depend on the detection of malware in a network. While analyzing malware samples can identify suspicious domains and help attribute network attacks to their sources, relying on samples to drive defensive actions gives malicious actors a critical time advantage to gather information and cause damage.

"Studies, including award-winning papers by our ECE colleagues, show that by the time malware is detected, it's already too late because the network communications and domain names used by the malware were active weeks or even months before the actual malware was discovered," said Farrell. "Findings such as these show that we need to fundamentally change the way we think about network defense."

Constant headlines about cybercrime may suggest that law enforcement is powerless to protect organizations and citizens, but Farrell is optimistic that investments like those being made in attribution will pay off.

"Right now, the advantage seems to be massively in favor of malicious actors," Farrell said. "But this will get better. It's a dynamic environment with constant back and forth. We are getting better tools and tradecraft of our own, along with the ability to use the principles of machine learning with the right signal information."

Borrowing a military phrase from kinetic operations, Farrell notes that detection of cyber events are too late "right of boom," after a malicious activity has taken place. "With our attribution research we are working to detect and identify malicious actors and their activity 'left of boom' to allow organizations more time to respond with better options," Farrell said.

ICSD
Project Profiles

COMMON OPERATING PICTURE FOR PUBLIC SECURITY

GTRI researchers have helped the Georgia Tech Police Department make better use of cameras and other sensors placed throughout the urban campus. The result is COP, or Common Operating Picture, a data visualization interface that allows police officers to obtain information from assets such as cameras, squad car sensors, and buildings through a single interface. Clicking on a building icon, for instance, causes a picture of the building to appear with options to view camera feeds and layouts of each floor. The goal of the new interface is to better use information resources during ongoing situations.

DEVELOPING A DIGITAL HEALTH PLATFORM

For the U.S. Department of Veterans Affairs (VA) and Veterans Health Administration (VHA), GTRI researchers brought together a team of public and private health care technology collaborators to develop a working and scalable proof-of-concept digital health platform (DHP) to support the departments' long-term vision. The open-source project demonstrated both proven and emerging technologies for interoperability and advanced functionality innovations from both the public and private sectors.

The proof-of-concept delivered capabilities that department leadership had identified to support clinical and operational policy and program transformation plans needed to address expected changes in veteran populations, service needs, and care delivery models.

The demonstration included the capability to obtain patient data from disparate military and commercial electronic records systems, and accept information from a broad range of ancillary services and consumer medical devices. Specific challenges from three groups of former service members were addressed: Iraq War veterans with traumatic brain injuries (TBIs), women veterans who need gender-specific services not traditionally provided by the VA, and Vietnam-era veterans who are now suffering age-related illnesses such as diabetes and congestive heart failure. TBIs alone affect some 87,000 veterans.

The overall project created 21 system application programming interfaces (APIs), which control how specific types of data flow into and out of the DHP. This included data exchanges with the Cerner Electronic Health Record (EHR) (representing the Department of Defense and a community hospital), Duke University Medical Center (Epic) as an academic medical provider, DocSnap personal health record (connecting to a Navy medicine pilot project), and personal health monitoring devices via Apple Healthkit and Validic.

Because the architecture is not tied to any proprietary system, the proof-of-concept accommodates future developments by connecting to and from other web services, apps, devices or electronic health systems that use the Fast Healthcare Interoperability Resources (FHIR) or other accepted industry open standards. The independence from commercial EHRs and the long-standing VistA showed that VA investments in VistA modernization and VHA investments in industry leading health care information technologies, such as telemedicine and home monitoring, could move forward within the DHP deployment cycle and not wait for full deployment.

An interdisciplinary team of researchers developed a working and scalable proof-of-concept digital health platform for the U.S. Department of Veterans Affairs and Veterans Health Administration. Shown (left-to-right, back row) are Myung Choi, GTRI senior research engineer; Steve Rushing, senior strategic advisor for health IT, Enterprise Innovation Institute; Jon Duke, director of the Center for Health Analytics & Informatics; Richard Starr, research scientist in the Institute for People and Technology; Margaret Wagner Dahl, associate vice president, health information technology & analytics in the Office of Industry Collaboration; (left-to-right, front row) Marla Gorges, GTRI research associate, and Eric Soto, GTRI research scientist.

ATOMIC MAGNETOMETER COULD HAVE MANY APPLICATIONS

Measuring very small changes in the brain's magnetic fields could lead to a better understanding of maladies such as epilepsy, post-traumatic stress disorder, and traumatic brain injury, but the equipment used for such measurements today is bulky and expensive. GTRI researchers are working to change that by creating a new generation of atomic magnetometers based on clouds of rubidium atoms that would be able to separate minuscule magnetic fields of interest from those created by the Earth and artificial sources. The project, which could also have navigation applications, will tackle the challenge by looking at both the basic physics and the signal processing required.

RUFIS: SECURITY CHECK FOR EMAIL

Emails can transport suspicious content, but GTRI cybersecurity researchers have developed a system to flag possible dubious file attachments that are hidden inside other files. The RecUrsive File Identification System (RUFIS) is like airport security screening for emails. A sender could exfiltrate sensitive information past the information technology network of an organization by slipping it into a larger package, like a ZIP file or a PowerPoint presentation. RUFIS can scan large data packages and identify embedded content using machine learning. The research is sponsored by the Air Force Research Laboratory's Cross Domain Group.

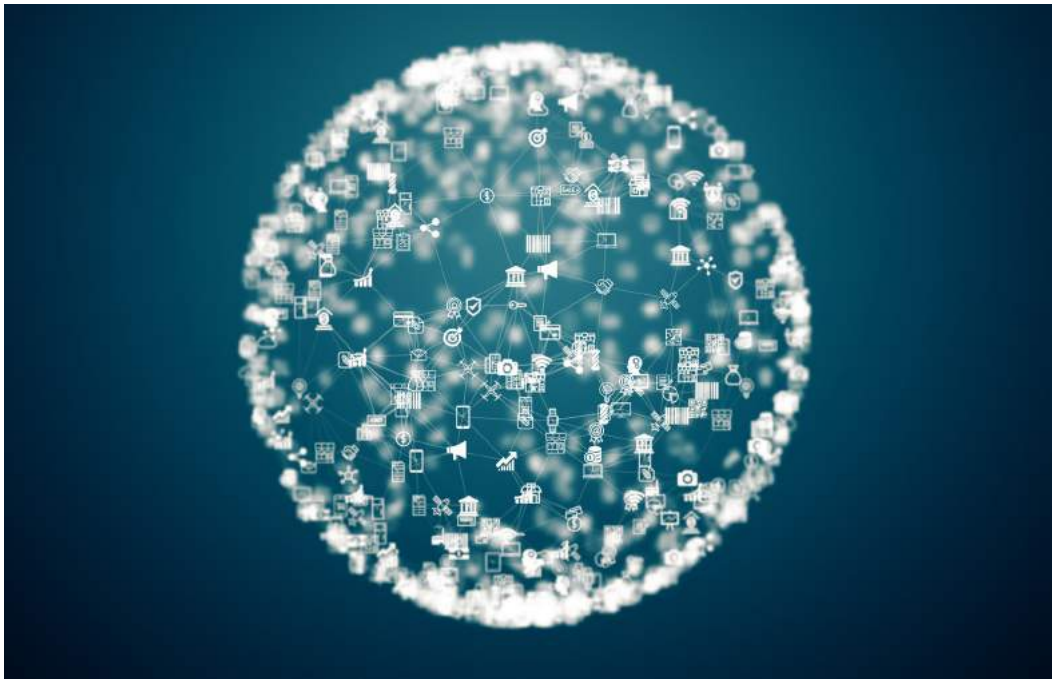
MODERNIZING INFORMATION SYSTEMS TO SUPPORT ARMY FAMILIES

The Army's Community Service (ACS) provides an array of social services to soldiers' families, including support for new parents, financial counseling, and help to find a job. Now, the ACS is looking ahead at novel ways to improve how services are delivered and is working with GTRI on a sweeping project to revamp its collection of information systems — key tools used by staff members providing services to Army families. The goal is to make the software smarter, faster, easier to use, and in the long run, enable Army leaders to leverage data from the systems to improve services in support of family and soldier readiness.

GTRI Senior Research Scientist Sheila Isbell and Senior Research Associate Margarita Gonzalez are helping the Army Community Service program revamp information systems used to provide an array of social services to the families of soldiers.

COLLABORATING ON THE INTERNET OF THINGS

GTRI is helping companies respond to market demand and develop their own Internet of Things (IoT) technologies and devices through the Center for the Development and Application of Internet of Things Technologies (CDAIT). Since 2014, nearly two dozen market-leading companies have joined the center and, through their active involvement on the board and working groups, have helped to shape IoT research activities. Through CDAIT, companies work together to address both technical questions — such as interoperability, device discovery, standards, and security — as well as management and societal issues, including how the IoT impacts business models, privacy, trust, ethics, regulation, and policy.



THE SENSORS AND INTELLIGENT SYSTEMS DIRECTORATE (SISD) AND LABORATORIES

In the **Sensors and Intelligent Systems Directorate (SISD)**, GTRI conducts fundamental and applied research to investigate, prototype, and deliver technological solutions to complex national security problems for the Department of Defense, intelligence agencies, and industry sponsors.

The Advanced Concepts Laboratory (ACL) identifies and transitions advances in fundamental and applied research for use in real-world applications, with emphasis on antennas, electromagnetics, quantum computing, and integrated analysis of signals and systems. ACL capabilities include numerical modeling, experimentation, and characterization capabilities devoted to computational electromagnetics, radar cross-section measurements, antenna characterization, electromagnetic materials characterization, experimental ion trapping for quantum computing and technology developments, and optical measures.

The Aerospace, Transportation and Advanced Systems Laboratory (ATAS) develops advanced technologies and systems from concept to prototype. ATAS focuses on the core areas of system simulations, and test and evaluations related to threat radars, missiles, air and ground vehicles, unmanned and autonomous systems, transportation systems, power and energy systems, acoustics, flow control, and food processing technologies. ATAS work demonstrates capabilities such as interoperability across unmanned air and ground vehicles, as well as in unmanned systems common control, collaborative autonomy, and payload integration.

The Sensors and Electromagnetic Applications Laboratory (SEAL) investigates and develops prototype radio/microwave frequency sensor systems with particular emphasis on radar systems engineering, electronics intelligence (ELINT), communications intelligence (COMINT), measurement and signal intelligence (MASINT), electromagnetic environmental effects, radar system performance modeling and simulation, sensor fusion, antenna technology, and electronic attack/electronic protection. SEAL develops advanced signal and data processing methods for acoustic sensors and multi-sensor intelligence exploitation architectures and algorithms covering all wavebands. SEAL also provides training courses in electronic defense topics.

Research Highlight

Student Teams Compete in Service Academies Swarm Challenge – with GTRI Assistance

What does the future of air-to-air combat sound like? At this point, it could sound very much like a swarm of angry bees.

That's how researcher Michael Day described the recent Defense Advanced Research Projects Agency (DARPA) Service Academies Swarm Challenge, which pitted mixed groups of up to 25 highly autonomous unmanned aerial vehicles (UAVs) on a side against one another in a next-generation version of the traditional "capture the flag" game. The friendly live-fly competition involved student teams from the U.S. Air Force Academy, the U.S. Military Academy, and the U.S. Naval Academy, with each team developing and testing its own innovative offensive and defensive tactics to conduct mock swarm-on-swarm battles.

Day, a research scientist at the Georgia Tech Research Institute (GTRI), co-led the support efforts required to stage the competition, working with the teams to help them operate the swarms, which included fixed-wing, propeller-driven Marcus UAV Zephyr aircraft, and DJI Flame Wheel quadcopters. GTRI coached the teams and shared its simulation software to help the competitors develop tactics for both protecting their own space and invading another team's base. Warren Lee, branch head for GTRI's Unmanned Flight Operations, co-led the project with Day.

The competition was sponsored by DARPA, which has a history of fostering competition to help advance cutting-edge technology. In addition to GTRI, the event was supported by the Naval Postgraduate School (NPS) and the Space and Naval Warfare Systems Command (SPAWAR). It was held in April 2017 at Camp Roberts, a California Army National Guard facility.

The vehicles were adapted from foam-wing radio-control hobbyist aircraft and rotorcraft designed to carry cameras. But these aerial vehicles were modified with computers that contained sophisticated autopilots, as well as separate computers that helped them coordinate with swarm teammates, locate opponents, and conduct offensive and defensive maneuvers — including aerial dogfights.

But the tactics weren't the only thing tested at the competition.

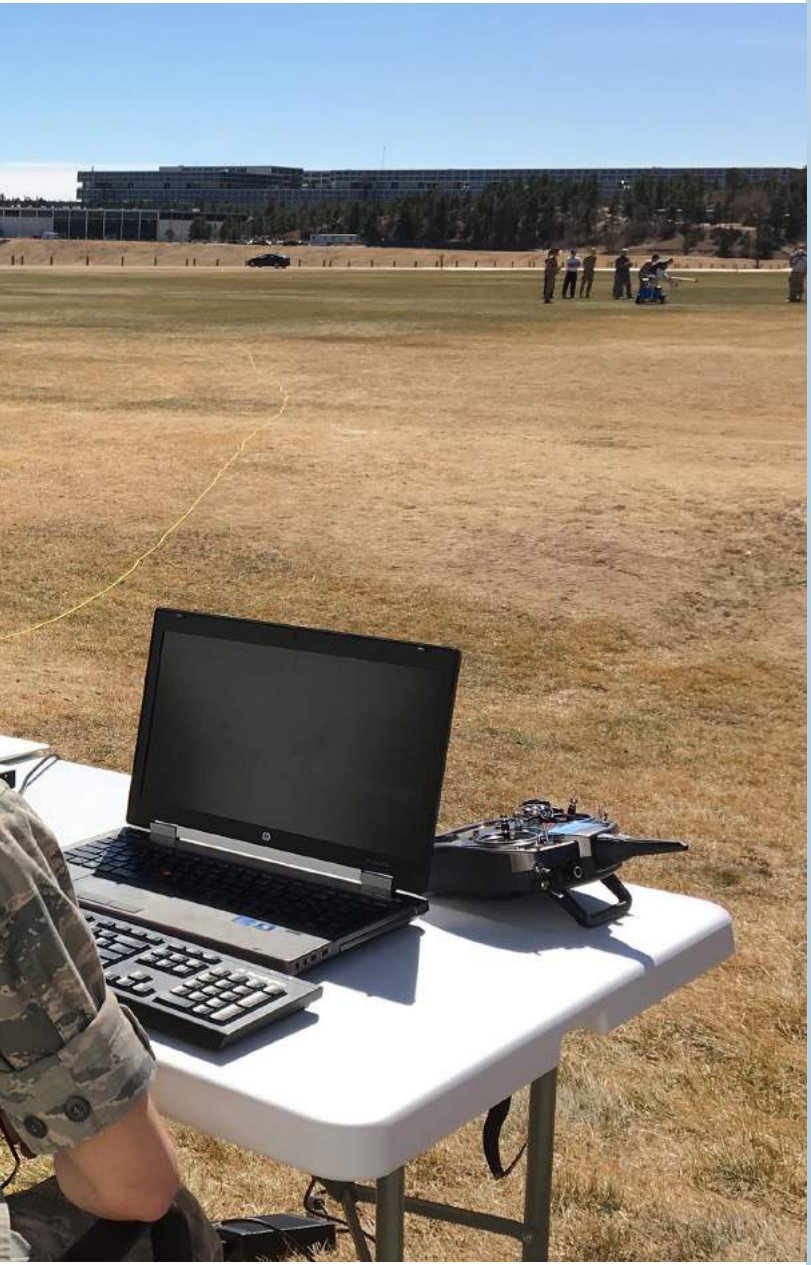
"A big challenge for us was logistical," said Day. "Getting this many aircraft ready to fly and launched safely in the brief window of time we had required a lot of preparation."

The competition was built on lessons learned from an earlier event that pitted GTRI researchers against colleagues from the Naval Postgraduate School. That competition involved swarms composed of 10 highly autonomous unmanned aircraft — all of them the same type — on each team.

BUILDING THE AIRCRAFT

Starting in August 2016, GTRI researchers began building and testing the aircraft slated for use in the competition. They built them in batches, assembling the basic vehicles, installing the electronics, and then testing them. Each of the fixed-wing aircraft had an autopilot, flight computer, two radios, a GPS receiver, and avionics to operate the flight controls.

Service academy team members monitor the competition from the ground. (DARPA image)



GTRI has years of experience incorporating autonomy into unmanned air vehicles, having conducted swarm research projects for agencies that include DARPA and the Office of Naval Research.

"Our operators and integrators are experienced, and we've gone through the highs and lows in terms of successes and failures," said Lee. "We felt extra pressure in this program to make sure that each and every aircraft was ready to fly so the teams could fully trust them and focus their efforts on the competition."

In all, Lee's group, which included Senior Research Engineer Gary Gray and Research Engineer Evan Hammac, built 144 aircraft — a mix of the foam-wing and quadcopter models. They were delivered to the service academies in time for students to become familiar with the aircraft operation. Members of GTRI's UAV team visited each of the academies twice to work with the cadets and midshipmen.

"It was exciting and very rewarding to be able to work with the students on this project," said Day. "They have a lot of demands on their time from their studies, so it was really hands-on and ambitious."

In addition to building and testing the aircraft and working with the students, GTRI also built seven NPS-designed launchers for the Zephyrs, which have a 54-inch wingspan. The launchers get the aircraft up to flight speed, accelerating the launch process — which was part of the overall competition.

"To get them all into the air, you can't spend more than about 30 seconds with each aircraft," noted Day, who was part of the GTRI group that supported the competition on the ground at Camp Roberts.

"When you have 30 aircraft in the sky, it's very different from when you only have five or 10," he said. "There's a higher level of stress because there are a lot more tasks to manage. We had a lot of lessons from our flight operations that we were able to share with the students."

Earlier, Lee's team built 65 Skywalker aircraft for the Low-Cost UAV Swarming Technology (LOCUST) program supported by the Office of Naval Research (ONR).

FLYING IN SIMULATION

In developing swarm tactics, GTRI relies heavily on simulation to prepare for actual flight tests. Computer time to run simulations is much less expensive than flying time, and allows for hundreds or thousands of test runs in the time that would be required for a single flight test.

"We can do testing in our laboratory using a variety of simulation tools and have the ability to run thousands of different scenarios, look at the results of different types of engagements, and then use machine learning techniques to hone in on new swarm-versus-swarm tactics," said Don Davis, division chief of GTRI's Robotics and Autonomous Systems Division. "In many cases, the simulation leads us to ideas we wouldn't have thought of if we had been bound by human experience in this area."

Among the tools used by the service academy teams was SCRIMMAGE (Simulating Collaborative Robots in a Massive Multi-Agent Game Environment), developed by GTRI researchers led by Senior Research Engineer Kevin DeMarco.

SCRIMMAGE allows the interactions of tens, hundreds, or even thousands of air vehicles to be studied simultaneously. The system's interface was designed to be familiar to anyone who has played video games.

"We can run the simulations faster than real time, so we can apply modern techniques that require much more data," said DeMarco. "We developed SCRIMMAGE to allow users to see exactly how a new algorithm is affecting an aircraft's flight maneuvers. We can run it on high-performance computing clusters to conduct millions of simulations and then have our machine-learning algorithms process that data to improve the algorithms."

The simulator doesn't run on the real aircraft, but does use the aircraft control software as part of its testing.

One of the combat tactics developed on SCRIMMAGE and used by the Service Academies Swarm Challenge aircraft is called "Greedy Shooter." Each UAV equipped with the software can locate the nearest enemy and go after it. The algorithm doesn't rely on collaboration among air vehicles, so multiple aircraft might attack the same enemy.

"In SCRIMMAGE, we have shown that you get a 50 percent success rate with this," said DeMarco.

But another algorithm developed by Senior Research Scientist Charles Pippin allows the air vehicles to allocate tasks, much as a human team may divide up the work that needs to be done on a project. "The vehicles can negotiate among themselves and decide who will be assigned to each target. There is no specific leader, but in a decentralized way, the aircraft make those decisions," DeMarco explained.

In the Swarm Challenge, each of the vehicles had information about all of the other vehicles, but in real combat situations, that wouldn't be the case. SCRIMMAGE is helping GTRI researchers determine how much information is needed to gain improvements from the task allocation model.

GTRI researchers are also comparing the swarm strategies against a legacy system — the old-fashioned "wingman" approach in which two aircraft work as a team. That simple approach has advantages over more complicated algorithms even when computers are tracking all the air vehicles.

"Lots of agents running simple algorithms can make swarms look more intelligent than they actually are," DeMarco said. "Our hypothesis is that by being able to solve the two-versus-two challenge, we may be able to extend what we learn to a swarm."

THE COMPETITION AND OUTCOME

At the three-day competition, service academy teams faced off against each other inside a "Battle Cube," a three-dimensional airspace 500 meters on a side and 78 meters above the ground. Each team was given 20 fixed-wing UAVs and 20 quadcopters and, under the Challenge rules, could select a mix of 25 vehicles (with five in reserve, for a total of 30) for each of the two 30-minute battle rounds.

Each team had to defend its flag — a large, inflatable ground target — while trying to score the most points. Points could be awarded in three ways: physically landing a UAV on the opponent's flag, simulated firing on an opponent's UAV, and launching as many aircraft as possible.

The U.S. Naval Academy was declared the winner of the competition. (Full information about the event is available at http://www.darpa.mil/news-events/2017-05-11).

In addition to helping advance swarm tactics, the competition also helped the next generation of Air Force, Army, and Navy leaders get a head start on future swarm technology. "This competition wasn't as much about who won and who lost as it was about offering hands-on insights about this quickly evolving and increasingly important technology," said Davis.

"GTRI is pleased to help train and equip the next generation of warfighters. Together, we showed that it is possible to get swarms of vehicles in the air and into mock combat against each other."

Among the lessons learned was the importance of rapidly launching the aircraft. Davis said the team able to get into the air first had an advantage over others. The competition also stretched the wireless networks used to communicate among the aircraft, and that will need improvement in the future.

"The biggest surprise to me was how well everything worked and how well the swarms operated," Davis said. "This is another step in developing the knowledge and experience required to use UAV swarms in the field. There's a lot more that needs to be done, but we're making progress."

In the future, highly autonomous vehicles could ultimately find uses throughout the military.

"UAVs will be extending the capabilities of the warfighter," Davis said. "I don't think we should expect swarms of UAVs to primarily just replace people. I think it's appropriate to think of UAVs as tools that warfighters can use to address a threat."

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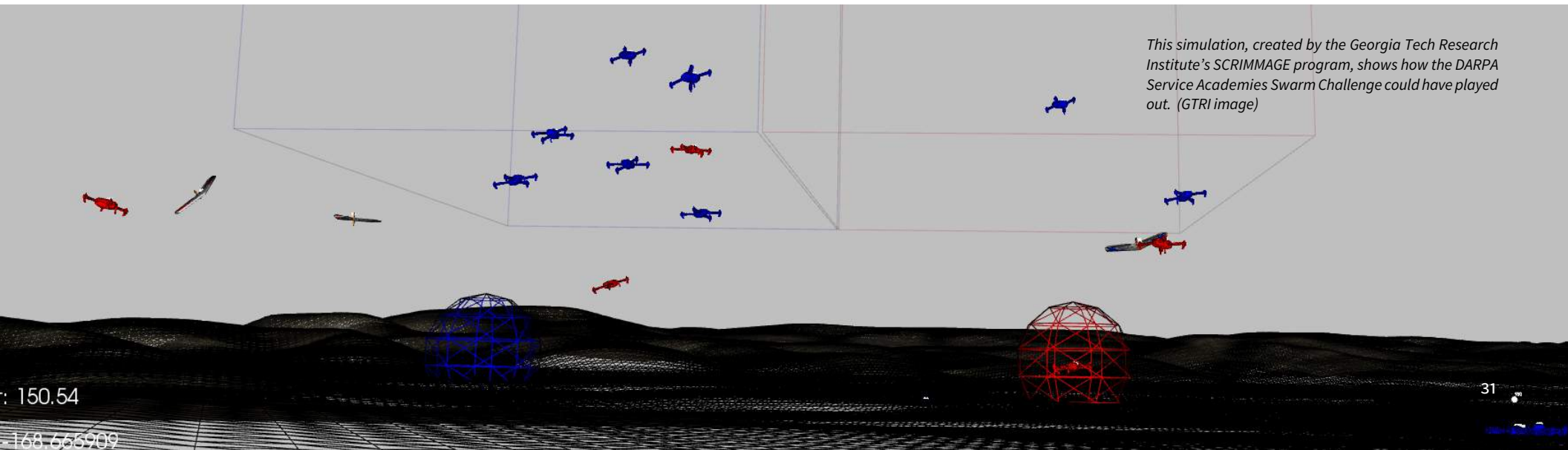
A Marcus AV Zephyr is being prepared for launch at the Service Academies Swarm Challenge. (DARPA image)



This simulation, created by the Georgia Tech Research Institute's SCRIMMAGE program, shows how the DARPA Service Academies Swarm Challenge could have played out. (GTRI image)

SISD
Project Profiles

SUPPORTING THE F-35 JOINT PROGRAM OFFICE'S F-35 ACCREDITATION PROGRAM

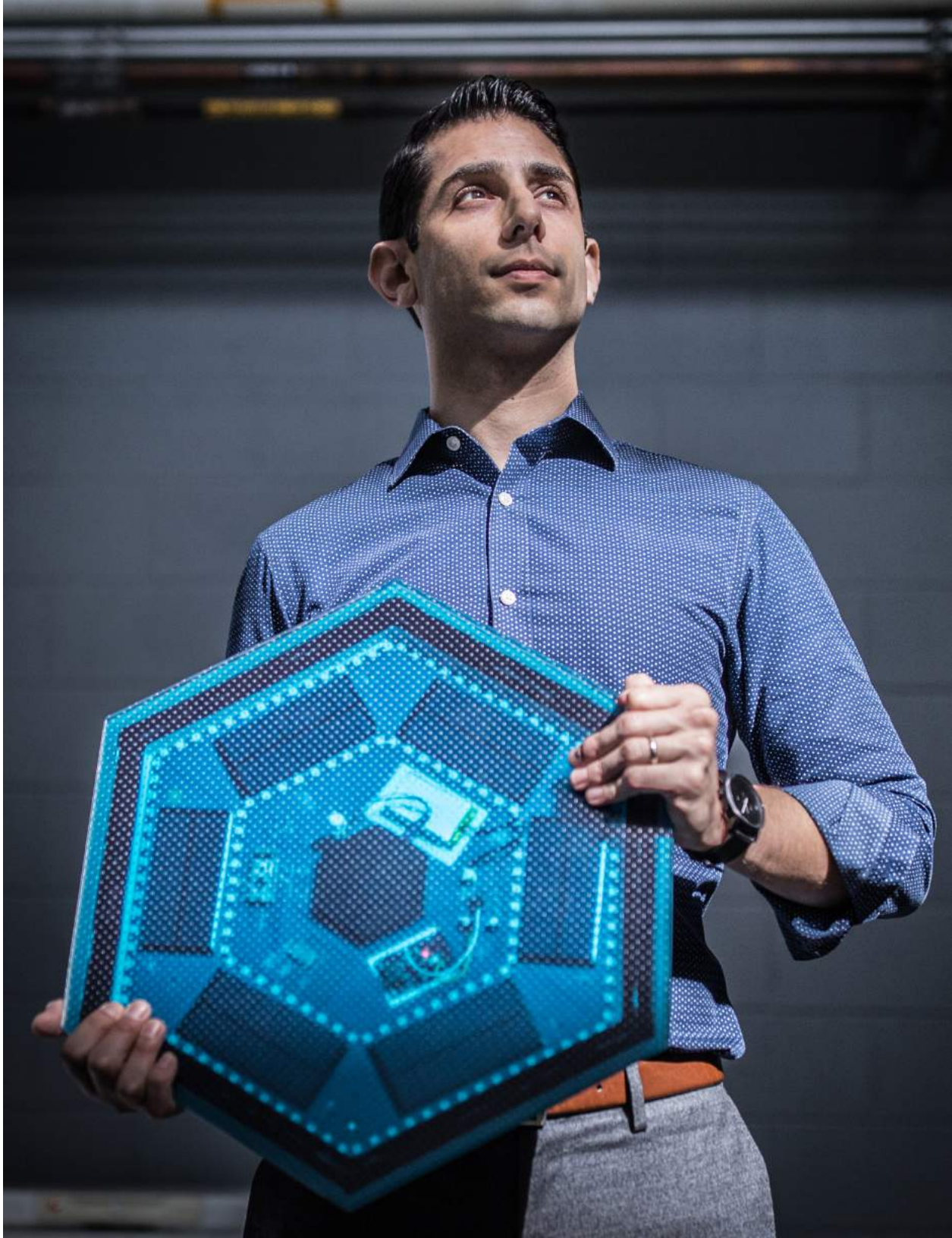
For the F-35 Joint Program Office, GTRI researchers are supporting a major initiative to collect, catalog, store, and analyze flight test and simulator data for the F-35 aircraft for the Joint Simulation Environment (JSE)/Integrated Battlespace Monitoring. Major tasks performed under the project involve performing quantitative analysis and providing subject matter expertise that will assist with the preparation of the F-35 JSE Initial Operational Test & Evaluation (IOT&E) accreditation package.

LEAF-PICKING ROBOT COLLECTS SAMPLES

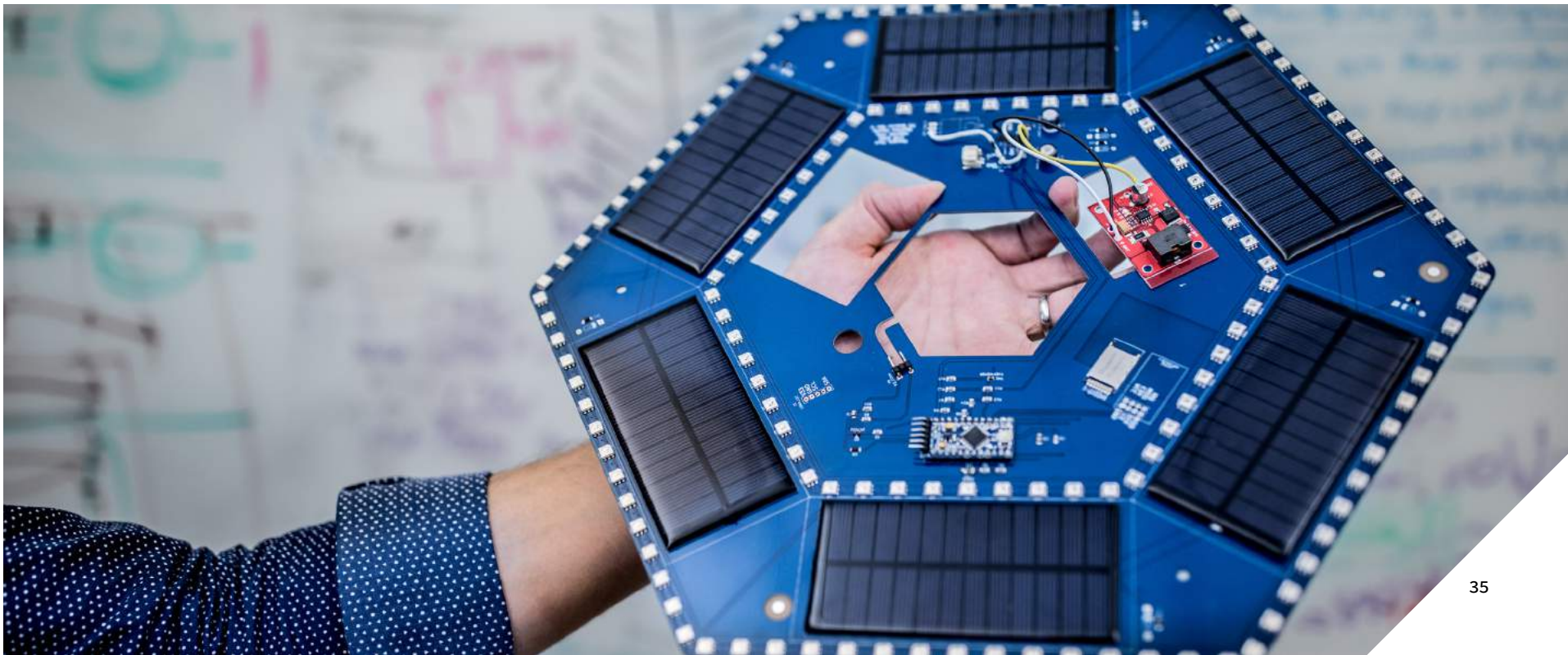
Farmers could receive earlier and more accurate warnings of unhealthy crop conditions as well as guidance that improves yields thanks to a leaf-picking robot being developed by Georgia Tech and University of Georgia researchers. The fully autonomous robotic system can collect soil and leaf samples from the field to identify stresses caused by drought or nutrient deficiencies. Farmers would use 4D models (3D plus time) of their fields to determine where potential problems exist, identifying locations where the robot should visit. GTRI researchers are collaborating with scientists from Georgia Tech's College of Computing on the U.S. Department of Agriculture-sponsored project.

PIEZOELECTRICITY LIGHTS THE WAY

Technology that could be used in self-powered smart cities of the future will soon be demonstrated at the NASA Kennedy Space Center's Visitor Complex at Cape Canaveral, Florida. GTRI and colleagues from Georgia Tech's School of Mechanical Engineering are collaborating on a project to build a 40,000-square-foot lighted outdoor footpath demonstrating applications of piezoelectricity. The installation, supported by NASA contractor Delaware North Corporation, will capture the small electrical charge generated when a piezoelectric material is compressed, flexed, or vibrated. The charge will help power an electronics package enclosed in glass-topped tiles, producing flashing lights and a wireless signal informing visitors about space missions and renewable energy.



Ilan Stern, a GTRI senior research scientist, displays piezoelectric tiles that will be used to create a lighted outdoor footpath at the NASA Kennedy Space Center Visitor Complex at Cape Canaveral, Florida.



ANTICIPATING EVENTS BY TRACKING INFORMATION

GTRI researchers are creating a high-performance system that analyzes real-world events across multiple news sources — and ultimately could be used to forecast future behavior. Known as Multi-Source Anticipatory Intelligence (MANIC), the system combines text, photos, satellite imagery, and readers' comments from news sources, extracts information, and analyzes the connectivity structure of the articles. The team is using deep-learning techniques in tandem with factor graphs, a technique for modeling probability distributions. The goal is to track changes in the news over time.

GTRI researchers are creating a high-performance system that analyzes real-world events across multiple news sources. Shown are Senior Research Scientists Zsolt Kira and Erica Briscoe, who are leading the project.

SWINGING ROBOT MONITORS CROPS

A two-armed robot swinging along elevated cables, could one day allow farmers to continuously monitor fields while avoiding interference with plants. The eight-pound robot has aluminum arms and 3D printed hands with sensors that allow it to swing from the overhead cables. A camera on the robot takes photos of the plants and transmits the images for analysis to provide early warning of disease or other stresses before these hazards can spread. The robot, which could replace other monitoring techniques and is also being explored for harvesting applications, is being developed by researchers from GTRI and Georgia Tech's School of Mechanical Engineering.

The Air Force Distributed Common Ground System (AF DCGS), also referred to as the AN/GSQ-272 SENTINEL weapon system, is the Air Force's primary intelligence, surveillance, and reconnaissance (ISR) collection, processing, exploitation, analysis, and dissemination (CPAD).

HELPING THE AIR FORCE SEARCH FOR ACTIONABLE INTELLIGENCE

Twenty-four hours a day, seven days a week, analysts huddle around computer screens in U.S. Air Force facilities around the world scanning for information that might require immediate action. These analysts are part of the Air Force Distributed Common Ground System (AF DCGS), which is designed to sift through vast amounts of information for "needles in the haystack" that are critical to national security. GTRI researchers are supporting the mission of AF DCGS by providing expertise from subject matter experts in a broad range of sensing areas, supporting the development and prototyping of new services needed by the Air Force, conducting training and technology transfer activities for DCGS personnel, and providing advice on the information technology that underlies the DCGS to the programmers who maintain and enhance the system.

LIGHTNING MAPPING ARRAY HELPS FORECAST SEVERE STORMS

A 12-node lightning mapping array operated by GTRI is providing data that could help the National Weather Service identify storms that may become severe. By measuring total lightning, the North Georgia Lightning Mapping Array detects storms whose intensity is increasing, making them more likely to spawn tornados or other severe weather. Data gathered by the network of lightning measurement instruments also supports research to improve storm forecasting. The array is operated by GTRI's Severe Storms Research Center, which is one of four GTRI programs supported directly by the State of Georgia. Beyond storm research, the center also provides meteorological expertise to other GTRI projects and operates K-12 STEM outreach programs.

John Trostel (right), director of the Severe Storms Research Center (SSRC), Tom Perry (left), an SSRC electrical engineer, and Madeline Frank (middle), a research meteorologist at the SSRC examine equipment for the North Georgia Lightning Mapping Array, a network of 12 sensors located around the metropolitan Atlanta area to detect lightning that may indicate storm intensification.

MAGNETIC TECHNIQUE REMOVES POLLUTANT

For decades, poultry producers have relied on an expensive and complicated process to treat the wastewater generated by food processing operations. Now, GTRI researchers are working on a new wastewater processing method that could save time, money, and potentially extract a valuable resource from the water. The process uses nanoparticles with magnetic properties to attach to the phosphorus pollutant. The particles and phosphorus are then removed magnetically, after which both can be separated. The work is being conducted under GTRI's Agricultural Technology Research Program with funding from the State of Georgia.

GTRI Principal Research Scientist Jie Xu is working on a new method for removing phosphorus from food processing wastewater using magnetic nanoparticles.

ROBOT TAKES ON CHICKEN-HOUSE TASKS

An autonomous robot could perform daily monitoring and maintenance tasks while safely interacting with animals in commercial chicken houses, helping to reduce the likelihood of disease, lessening labor costs — and allowing farmers to take on more important activities. The GTRI robot addresses challenges of operating in environments that have dynamic, unpredictable obstacles — such as chickens — and uses ultrasonic and light-based systems to determine its own location. In addition to monitoring, the robot can handle manual tasks such as retrieving eggs. The research, done in collaboration with the University of Georgia, was sponsored by the Agricultural Technology Research Program through the State of Georgia.

A GTRI robot navigates its way through a chicken grow-out house to search for eggs and monitor the condition of the flock.

Co-op students Jennifer Grigsby and Alison McGarey assemble a surrogate circular disk to validate encoder electronics for an airborne LIDAR system circular scanner.


ADVANCED IMAGING AND SENSOR CONCEPTS

STATE OF GEORGIA PROGRAMS

CREATED TO DISCOVER FOR GEORGIA

When a group of Georgia legislators and regents founded the Georgia Tech Research Institute (GTRI), originally named the State Engineering Experiment Station (EES), they tasked researchers to explore engineering, manufacturing, and science-related solutions for some of the nation's toughest problems.

Through annual funding from the State of Georgia, GTRI manages several programs that work to strengthen statewide ecosystems through innovative technologies that advance STEM education (page 50), agricultural production, energy and sustainability practices, and severe storms weather forecasting.

AGRICULTURAL TECHNOLOGY RESEARCH PROGRAM (ATRP)

ATRP works closely with Georgia agribusiness, especially the poultry industry, to apply and/or develop innovative engineering-based technologies that address a number of food safety, animal well-being, worker safety, and environmental sustainability challenges. Many developments have resulted in commercialized products and provided direct economic benefit to poultry processors.

ENERGY AND SUSTAINABILITY RESEARCH GROUP (ESRG)

ESRG conducts innovative research in the areas of energy, sustainable practices, water, and advanced materials for the benefit of Georgia's citizens and businesses. Developments include water purification and filtration technologies, lower cost solar technologies, graphene-based storage technologies, piezoelectric materials, nanomaterials, and renewable energy systems.

SEVERE STORMS RESEARCH CENTER (SSRC)

SSRC serves as a focal point for severe weather research in Georgia. The Center is actively engaged in developing alternative methods of detecting and forecasting severe local storms, exploring improvements to existing storm prediction and sensor technology, and researching local and global factors that influence the development and detection of severe local storms. Expanding severe weather awareness through community outreach is an important part of the SSRC charter.

Georgia companies and facilities supported by research projects — **34**

Technical assistance services provided to companies and individuals across the state — **91**

Outside investment attracted by state-funded research programs — **Over $2.5 million**

TECHNOLOGY AND INNOVATION

GTRI's chief technology officer (CTO) leads GTRI's scientific and technological preeminence through a portfolio of independent research and development (IRAD) projects. The CTO also selects the appointment of GTRI Fellows, leads research interactions across a network of laboratory-based chief scientists, supports the selection of Georgia Tech's teaching fellowships, and is the editor of an internal IRAD journal publication designed to share information about GTRI's annual research accomplishments.

INDEPENDENT RESEARCH AND DEVELOPMENT (IRAD)

The purpose of GTRI's IRAD investments is to develop and advance research that addresses national security and global challenges. These ventures extend GTRI's research base, sustain its competitive position in critical research areas, foster exploration and innovation in new technical areas, and accelerate the organization's entry into areas of high interest to sponsors.

GTRI invests its IRAD funds through three main portfolios of research projects: strategic initiatives, tactical/lab discretionary initiatives, and Hives initiatives.

Strategic initiatives develop significant capabilities in areas of national security and global importance. They substantially advance GTRI's existing research strengths, and can be bold forays into somewhat uncharted territory for which GTRI has the technical acumen.

Tactical and lab-discretionary initiatives are funded in response to known sponsor interests, to address technology gaps, and stay ahead of potential opportunities. They are more high-risk/high-payoff projects, and may be quick-reaction or purely exploratory.

Hives initiatives explore the disruption created by the convergence of commodity technologies with global trends. They explore the co-evolution of technology with concept of operations (CONOPS), and they anticipate the growth of new security challenges arising from ambiguous warfare.

GTRI FELLOWS

The title of GTRI Fellow is granted to outstanding full-time principal researchers employed by GTRI based on a competitive review process that evaluates technical achievements and cross-organizational developments aligned with critical GTRI research. GTRI Fellows are technically renowned, and their research significantly advances the GTRI strategy.

GEORGIA TECH TEACHING FELLOWS

As an integral part of Georgia Tech, GTRI supports the educational mission of the Institute by teaching courses in academic departments and through Georgia Tech's Professional Education program. The GTRI chief technology officer supports selection of top researchers for participation in teaching opportunities through a competitive process administered by Georgia Tech's executive vice president for research.

GTRI DEPUTY DIRECTOR FOR RESEARCH AND CHIEF TECHNOLOGY OFFICER

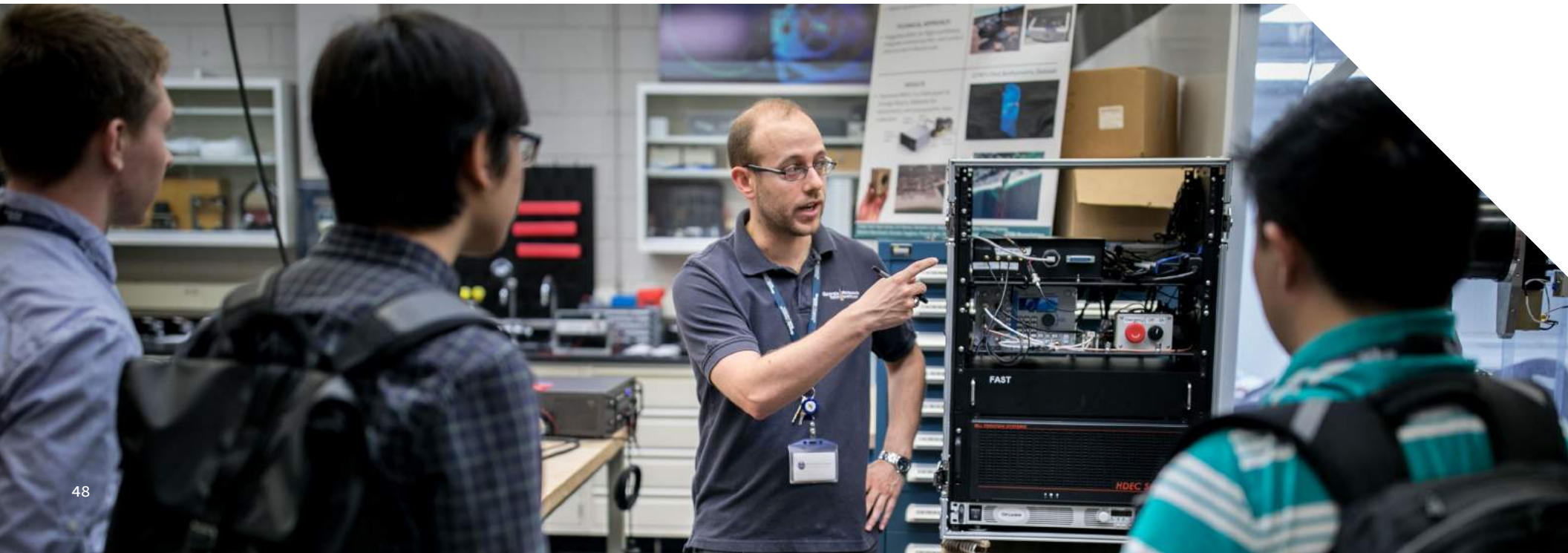
Since 2014, Lora G. Weiss, Ph.D., has served as GTRI's chief technology officer (CTO), where she is responsible for the portfolio of independent research and development investments. Weiss' personal research is on the design, development, and implementation of technologies for unmanned and autonomous systems and the associated signal processing.

For more than 25 years, she has been responsible for advancing capabilities of systems spanning the domains of unmanned air, ground, sea surface, and undersea systems. She is a published researcher who has been featured in several highly regarded journal publications, including her 1994 seminal paper featured on the cover of the internationally renowned IEEE Signal Processing magazine and again in 2011 for her cover story in IEEE Spectrum.

Weiss was on the board of directors for the Association of Unmanned Vehicle Systems International (AUVSI), which is the world's largest unmanned systems organization and was on the technical advisory board of the National Robotics Technology Consortium. Weiss was also a member of the Steering Committee for the Information Science and Technology Study Group for DARPA; she was an executive board member for the National Defense Industrial Association's (NDIA) Undersea Warfare Division; she supported the National Academies' Naval Studies Board on mainstreaming unmanned underwater vehicles into the Navy and on multi-domain autonomous systems for U.S. Naval forces; and she supported the Center for New American Security's Future Foundry Task Force. Currently, she chairs the international American Society for Testing and Materials (ASTM) Committee on Unmanned Maritime Vehicle Autonomy and Control.

Weiss received her B.S. in Mathematics from Boston University magna cum laude, her M.S. in Mathematics from the University of California Los Angeles, and her Ph.D. in Acoustics from The Pennsylvania State University. Weiss is an award-winning researcher who received a Letter of Commendation from the Chief of Naval Operations Strategic Studies Group in 2013.

GEORGIA TECH COLLABORATIONS



GEORGIA TECH COLLABORATIONS

GTRI is an integral part of Georgia Tech, one of the nation's top public universities and an international leader in engineering, science, design, computer technology, policy, and many other areas of education and research. That connection allows Georgia Tech's academic faculty and students to work alongside GTRI researchers to solve the toughest challenges facing our sponsors.

U.S. News & World Report ranks Georgia Tech eighth overall among the nation's top public universities, and fourth among undergraduate engineering programs. Georgia Tech has over 3,000 academic and research faculty, and more than 25,000 graduate and undergraduate students. Georgia Tech's research expenditures totaled over $824 million for the Fiscal Year 2017.

GTRI is the largest employer of Georgia Tech students, who bring their creativity and innovation to research projects and often join the research team as full-time researchers. During the Fiscal Year 2017, 595 graduate and undergraduate students contributed to major sponsored research programs in GTRI.

Researchers help teach academic courses, and share their knowledge through professional education opportunities. In the Fiscal Year 2017, GTRI had six research faculty enrolled in its teaching fellows program and other GTRI personnel who taught for various academic schools. Researchers taught 105 professional education courses in such areas as radar, aerospace design, acoustics, electronic systems, and robotics with 336 GTRI researchers involved in robotics instruction.

This collaboration with Georgia Tech's six colleges manifests in a variety of ways, allowing GTRI to amplify this powerful core of academic research to solve the critical issues facing GTRI sponsors.

The following are some examples of collaborations — both research-focused and academic-focused — conducted between Georgia Tech and GTRI.

Four of Georgia Tech's Interdisciplinary Research Institutes (IRI) have strong ties to GTRI.

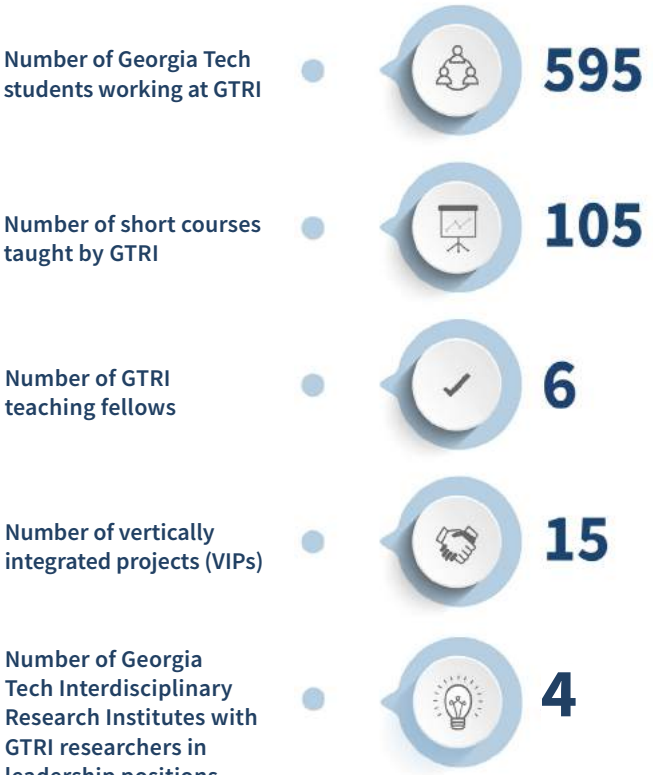
- The Institute for Information Security & Privacy (IISP): Co-director Mike Farrell, GTRI chief strategist of the Cybersecurity, Information Protection, and Hardware Evaluation Research Laboratory (CIPHER).
- The Institute for People and Technology (IPaT): Deputy Director Leigh McCook, GTRI principal research associate for the Information and Communications Laboratory (ICL).
- Institute for Robotics and Intelligent Machines: Associate Director Gary McMurray, division chief of the Food Processing Technology Division.
- The Institute for Materials: Deputy Director Jud Ready, GTRI principal research engineer for the Electro-Optical Systems Laboratory (EOSL).

GTRI's researchers work with hundreds of Georgia Tech graduate and undergraduate students to develop the next generation of scientists and engineers. Some of those activities include undergraduate students in Capstone Design projects, which are real-world, open-ended and interdisciplinary challenges. Additional student collaborations are vertically integrated projects (VIPs), in the areas of :

- 2D Heterostructure Synthesis.
- Advanced Graphene Battery Technology.
- Aquabots: Maritime Robotics.
- Automated Algorithm Design.
- Automotive LIDAR.
- Chip Scale Power & Energy (NOFORN).
- Configurable Computing & Embedded Systems.
- Embedded System Cybersecurity.
- Georgia Tech Mobile STEM Laboratory.
- GTRI Agricultural Robotics.
- Holo-Jackets.
- HumaniTech.
- Intelligent Platform for Crowdsourcing (IP Crowd).
- JetPack-X 4Mars.
- M.A.R.S.: Martian Advanced Renewable Systems.

During the Fiscal Year 2017, GTRI piloted a 10-week summer Research Internship Program that hired 49 Georgia Tech undergraduate students, who as a group held an average 3.66 GPA. Seven GTRI labs along with the Warner Robins Field Office participated as employers and mentors to students who span academic majors from aerospace engineering to international affairs.

Through the Office of the Executive Vice President for Research, GTRI researchers can apply to become Research Faculty Teaching Fellows, offering research faculty members the opportunity to become first-time instructors, as well as offer previous instructors the ability to take their cutting-edge research and use it for instructional programs at Georgia Tech.



DIVERSITY, INCLUSION, OUTREACH, AND EDUCATION

DIVERSITY AND INCLUSION

GTRI's commitment to diversity and inclusion (D&I) is vital not only to our growth, but to sustaining inclusive excellence.

We understand that a commitment to inclusion helps us sustain a workforce of engaged, motivated, and driven people. This approach toward achieving inclusive excellence ensures that we will be able to widen our solution offerings for our sponsors and continue our dynamic growth.

Our vision is to build and sustain an environment where our people are valued for who they are, enabling them to cultivate inclusive, high performing, and innovative teams that solve complex problems.

Highlights include:

- Established the Diversity and Inclusion Division at GTRI in the summer of 2016.
- Launched the Diversity and Inclusion Council, fall of 2016, to serve as an advisory council to the Diversity and Inclusion Division. The Council is comprised of over 60 GTRI employees across laboratories and business units, with representation from entry level, middle management, and senior leadership.
- Awarded five Georgia Tech female and underrepresented students with $10,000 scholarships. The scholarships support women and underrepresented students during their collegiate career with a goal of increasing the population of diverse scientists, engineers, and technologists.
- Continued research and development opportunities for summer cadets through GTRI's U.S. Air Force Academy Cadet Summer Research Program (CSRP).

PROFESSIONAL EDUCATION

GTRI fulfills an educational mission in addition to research and development. GTRI delivers short courses and certificate programs in defense technology, cybersecurity, problem-solving, and occupational safety and health through Georgia Tech Professional Education. There are 105 defense technology courses and 58 safety and health courses, as well as 24 professional certificates offered in both disciplines. Professional master's degrees have grown in popularity for the division. The Professional Master's in Applied Systems Engineering (PMASE) graduated 131 students and a new Professional Master's in Occupational Safety and Health (PMOSH) launched in February 2017 – first of its kind in Georgia.

ELEVATING STEM THROUGH EDUCATOR AND STUDENT OUTREACH

The mission of STEM@GTRI is to inspire, engage, and impact students, administrators, and educators in the K-12 science, technology, engineering, and mathematics (STEM) pipeline. Through programs including technical assistance to schools, outreach events, summer and year-long internships in GTRI laboratories, we endeavor to introduce students to STEM disciplines and to ignite their interest in STEM for post-secondary education and careers.

Under STEM@GTRI, D2D@GT — or Direct to Discovery at Georgia Tech — was created to connect classrooms via high-speed video bandwidth with Georgia Tech labs, bridging world-class researchers, and their laboratories to K-12 classrooms. During the 2016-2017 school year, D2D@GT connected with 60 counties around Georgia.

Since 1996, STEM@GTRI has reached educators and students with one mission in mind: change the future of STEM by equipping teachers and elevating students' attention with GTRI's renowned educational resources and research. In Fiscal Year 2016, STEM@GTRI reached more than 8,100 students and 650 teachers through various activities and events, like the SeaPerch Competition and Project ENGAGES. Along with those initiatives, here are additional highlights from the year:

ENGAGING HIGH SCHOOL STUDENTS

Each year, a dozen or so students from Atlanta high schools serving underrepresented communities leap into a high-intensity program to explore engineering research, learn about possibilities for future STEM careers, and gain confidence in their abilities. Twelve students from six Atlanta public schools achieved placement in the engineering track of Project ENGAGES (Engaging New Generations at Georgia Tech through Engineering & Science) for the 2017-2018 school year. Each student developed a research project, working one-on-one with a scientist as part of a funded study in a Georgia Tech lab. GTRI manages this track for fields such as robotics, materials, and environmental engineering.

THE ATLANTA BRAVES

Through a collaboration between STEM@GTRI, the Center for Education Integrating Science, Mathematics, and Computing, and The Atlanta Braves, seven metro middle school teachers and students were brought together to apply the concepts of science, technology, engineering, art, and math (STEAM) to one of the nation's oldest pastimes — baseball. After a year's worth of professional development for teachers and sharing curriculum modules with students, each school reviewed their competition kit — supplied by GTRI physicists and manufactured by the Georgia Tech Machine Shop — as a guide for their pitching innovations. Students from the Atlanta Public Schools and Cobb County School District developed what might be the newest pitching tool, coined the "Tomahawk Tosser" — a winning name submitted by a Cobb County middle school student.

THOMSON MIDDLE SCHOOL

GTRI has been working with the Houston County School System for the past two years presenting enrichment activities to sixth grade math and science classes. The activities span five weeks during a 10-week topic cycle at Thomson Middle School in Centerville, Georgia. The partnership between the Houston County Board of Education, teachers and

administrators at the school, and GTRI, has greatly improved students' in-classroom performance and standardized test scores. The Houston County Board of Education Science Instructional Coach developed pre- and post-tests to measure the impact of GTRI activities compared to a control middle school with results showing a dramatic increase in standardized test scores, raising Thomson Middle School's rank to third, among eight middle schools in the county.

CODING ACROSS GEORGIA

GTRI received funding from the Governor's Office of Student Achievement (GOSA) Innovation Fund to implement two computer science, coding, and applied mathematics grants. The first grant, Coding Across Georgia, or CAG, is a collaboration with Tift County Schools, the Savannah-Chatham County Public School System, Savannah State University, and Armstrong State University. Both school districts applied their learnings to the issue of access to quality water — a recognized local problem.

In Tift County, teachers and their students developed an intention irrigation system with farm-based moisture sensors where both the students and GTRI researchers grew tomatoes in sensor-equipped gardens. In Savannah-Chatham, students and teachers developed algae detection sensors because of the significant impact algae blooms have on the coastal hospitality industry. Students at the Oglethorpe Charter School were able to collaborate with researchers at GTRI to compare algae growth between two simulated settings.

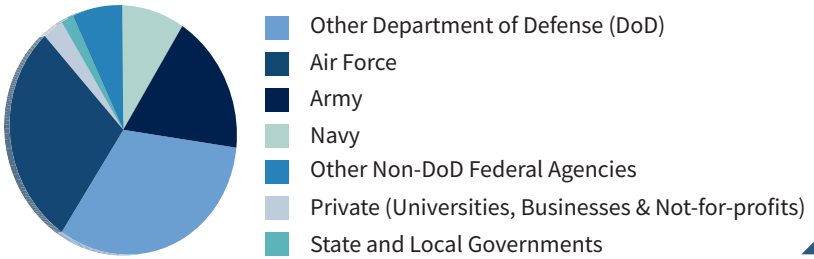
YOUNG ROBOTICS ENGINEERS COMPETE IN SEAPERCH

In May 2017, GTRI helped host hundreds of young robotics engineers competing in the seventh National SeaPerch Underwater Robotics Championship. About 900 students in 188 teams — regional winners from middle and high schools as well as two elementary school teams — launched their underwater remotely operated vehicles at Georgia Tech's McAuley Aquatic Center. In total, more than 1,500 students, teachers, coaches, family members, guests, and volunteers participated. SeaPerch is an innovative program sponsored by the Office of Naval Research and managed by the Association for Unmanned Vehicle Systems International (AUVSI).

GTRI researchers are active in promoting science and technology to K-12 students. This photo shows Senior Research Scientist Jack Wood interacting with students during a Laser Fest program.

FINANCIAL STATEMENT

During the fiscal year that ended June 30, 2018, GTRI, a non-profit applied research and development organization, recorded revenue from research contracts totaling $449 million, compared with $382 million for the previous fiscal year. Contract awards for the fiscal year reached $497 million, surpassing the previous year's total of $377 million.



Private (Universities, Businesses & Not-for-profits)	$15M
State and Local Governments	$8M
Other Non-DoD Federal Agencies	$30M
Navy	$101M
Army	$84M
Air Force	$110M
Other DoD	$101M
Total	$449M

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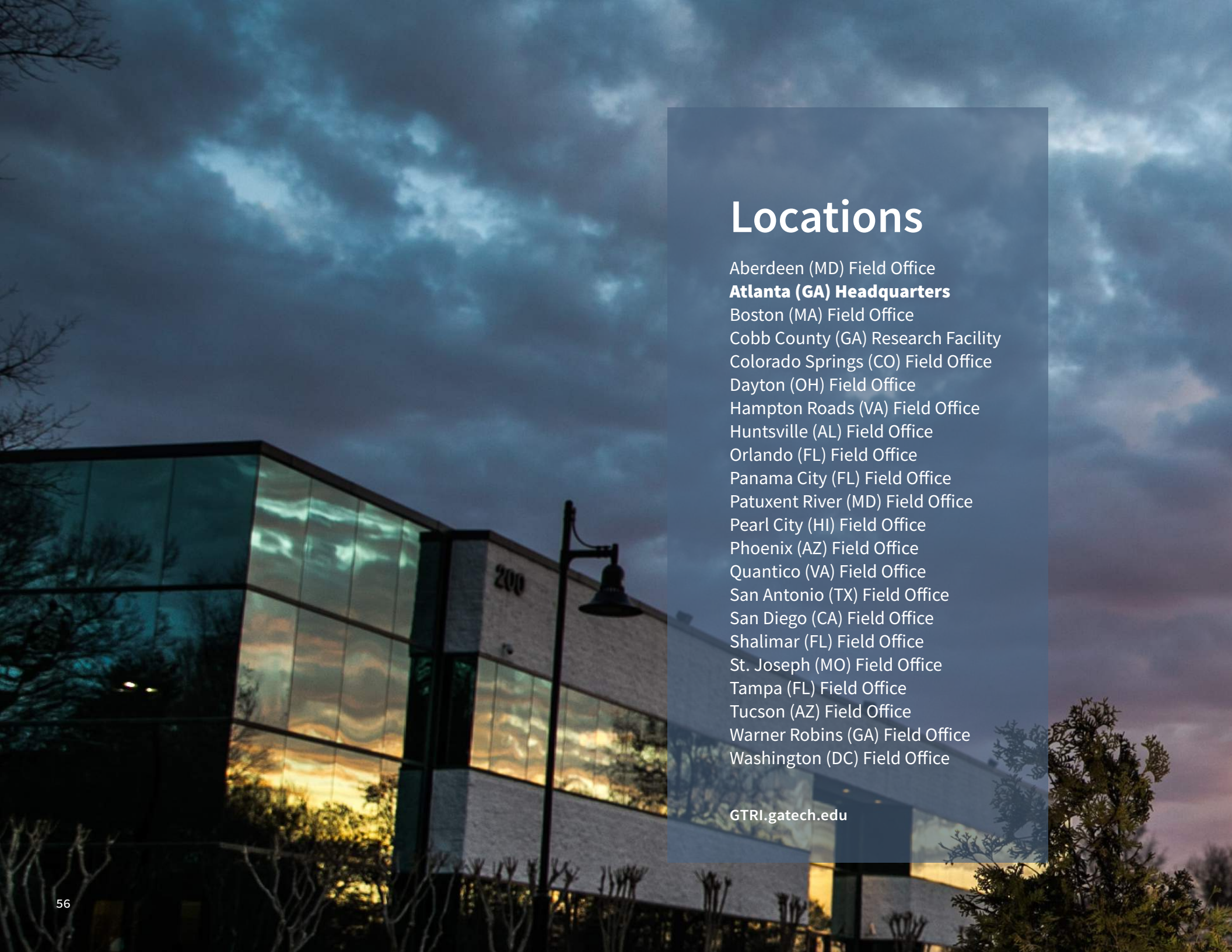

Locations

Aberdeen (MD) Field Office
Atlanta (GA) Headquarters
Boston (MA) Field Office
Cobb County (GA) Research Facility
Colorado Springs (CO) Field Office
Dayton (OH) Field Office
Hampton Roads (VA) Field Office
Huntsville (AL) Field Office
Orlando (FL) Field Office
Panama City (FL) Field Office
Patuxent River (MD) Field Office
Pearl City (HI) Field Office
Phoenix (AZ) Field Office
Quantico (VA) Field Office
San Antonio (TX) Field Office
San Diego (CA) Field Office
Shalimar (FL) Field Office
St. Joseph (MO) Field Office
Tampa (FL) Field Office
Tucson (AZ) Field Office
Warner Robins (GA) Field Office
Washington (DC) Field Office

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Georgia Tech
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GTRI RECOGNITIONS

Atlanta Business Chronicle
Chief Financial Officer of the Year Award
Rebecca Caravati

General Curtis LeMay Institute's
for the Art of Persuasion
"Most Likely to Have it His Way" Award
Rusty Roberts

Higgins Lifetime Achievement Award
Dan Ortiz

IEEE Senior Members
Chris Bailey
Jeff Connor
Rob Hemphill
Melanie Hill
Joe Lanza
Doug Martin
Phillip Moore
Brian Mulvaney
William Rowe
Lance Schmieder
Jim Skala
Alex Trzecieski
Ryan Westafer

IEEE USA Award for Furthering Public Understanding and Advancement of the Engineering Profession
John Toon

IEEE Aerospace and Electronic Systems Carlton Best Paper Award
Jim Sangston

IEEE Outstanding Company Award – Huntsville Section
Applied Systems Laboratory (ASL)

IEEE Outstanding Engineer Award – Huntsville Section
Glenn Parker

James S. Cogswell Outstanding Industrial Security Achievement Award
Warner Robins Field Office

MDA 13th Annual Award for the System Engineering Team
David Aalfs
Kristin Bing
Fred McKeen

University of Alabama in Huntsville Alumni Association Board of Directors, Board Member of the Year
Eric Grigorian

Western Conference and Exposition Copernicus Award
Jim Parson

Women in Technology - Woman of the Year Award
Jill Gostin

2017-2018 GTRI BOOK AUTHORS

Megan Denham (ICL) Chapter Co-author
"Three Faces of Psychogenic Nonepileptic Seizures," *Neuropsychological Evaluation of Somatoform and Other Functional Somatic Conditions: Assessment Primer*: Taylor & Francis, 2017.

Dane Freeman (ELSYS) Chapter Author
Tom McDermott (ELSYS) Chapter Author
"Systems Thinking in the Systems Engineering Process, New Methods and Tools," Frank, M., Shaked, H., and Kordova, S. (Eds.), *Systems Thinking: Foundation, Uses and Challenges*, New York, NY: Nova Science, 2016.

Mike Harris (ELSYS) Author
Transmit Receive Modules for Radar and Communication Systems: Artech House, 2016.

Margaret Loper (ICL) Chapter Co-author
"Academic Education Supporting the Professional Landscape," The Profession of Modeling and Simulation: Wiley Publishing, 2017.

Margaret Loper (ICL) Chapter Co-author
"Introduction to Modeling & Simulation," "Computational Challenges in Modeling and Simulation," *Research Challenges in Modeling and Simulation for Engineering Complex Systems:* Springer, 2017.

Margaret Loper (ICL) Chapter Co-author
"Situational Awareness in Megacities," Kosal, Margaret. E. (Ed.), *Technology and the Intelligence Community Challenges and Advances for the 21st Century:* Springer, 2018.

Bassem R. Mahafza (SEAL) Author
Introduction to Radar Analysis (Advances in Applied Mathematics): Chapman and Hall/CRC Press, 2nd Edition, 2017.

Rick Moore (ACL) Author
Electromagnetic Composites Handbook: Models, Measurement and Characteristics, McGraw Hill, 2nd Edition, 2016.

Jim Sangston (SEAL) Chapter Author
"Geometric Foundations for Radar Signal Processing," *Academic Press Library in Signal Processing Volume 7, Array, Radar and Communications Engineering*: Academic Press, 2017.

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