Georgia Tech Research Institute

GTRI

2015-2016 YEAR IN REVIEW

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WELCOME

MESSAGE FROM THE DIRECTOR

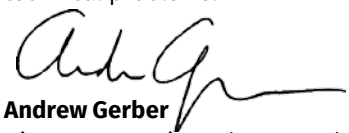
The **Georgia Tech Research Institute (GTRI)** develops advanced technology solutions and large-scale system prototypes to address the most difficult problems in national security, economic development, and overall human betterment. As an integral part of the Georgia Institute of Technology (Georgia Tech)—recognized among the top engineering institutions in the world—we are deeply connected across campus at all levels, especially via the more than 500 undergraduate and graduate students who work at GTRI each year.

Fiscal years 2015 - 2016 saw a number of changes at GTRI. First, I had the honor of joining as the new director of GTRI and senior vice president of Georgia Tech in August 2015. Our sponsored research awards have continued to grow, setting a new record in 2016, and there continues to be a strong demand signal for the work that we are doing, particularly in the national security arena. As we all know, these are exceedingly complex times on the national security front, and new technological approaches are needed to help address the challenges facing our nation from multiple directions. That is what GTRI is about: Taking the best ideas, often co-developed with our Georgia Tech academic partners, and turning them into systems applications that provide a significant technological advantage over more conventional approaches. Our researchers take tremendous pride in what they do, and their greatest reward comes from seeing their technical solutions providing new levels of capability for our armed forces, our federal and state sponsors, our industry partners, and those with whom we collaborate worldwide.

Some significant accomplishments in 2015 - 2016 include:

- Development and demonstration of swarms of 30 unmanned aerial vehicles (UAVs) in which the swarm is fully autonomous and collaborates dynamically to achieve changing mission objectives;
- Development of a phased-array antenna where each antenna element is itself an array of interconnected radio-frequency switches that can be reconfigured via software to optimize performance;
- Development of a multi-qubit chip based on trapped ion technology for future quantum computing applications, and demonstration of a simple computational algorithm;
- Continued development and propagation across the Services of the “Angry Kitten” family of jammer pods, used for testing and development of new technology for electronic warfare;
- Development and test flights of a light detection and ranging (LIDAR) system capable of producing real-time 3-D imagery with total propagated uncertainty for bathymetric and foliage penetrating applications;
- Development of insider threat and anomaly detection systems that help protect organizations by monitoring computer networks for abnormal activity;
- Launching of a new Institute for Information Security and Privacy along with the College of Computing to help translate the significant advances in cyber technology made in the academic and national security domains to the commercial sector;
- Achievement of ISO 9001 certification for our Electronic Systems Laboratory to ensure quality control and mission assurance for our larger prototyping projects.

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 invite you to read through this summary of 2015 - 2016 technical accomplishments, research investments, and outreach programs. I also invite you to follow up and engage with us. Let us know how our work is impacting your mission, and let GTRI help you find solutions to your most challenging technical problems.



Andrew Gerber
Director, Georgia Tech Research Institute
Senior Vice President, Georgia Institute of Technology

"GTRI is about taking the best ideas, often co-developed with our Georgia Tech academic partners, and turning them into systems applications that provide a significant technological advantage over more conventional approaches."

GEORGIA TECH RESEARCH INSTITUTE

GTRI Quick Overview

The Georgia Tech Research Institute (GTRI) is a highly regarded applied research and development organization that is part of the Georgia Institute of Technology, one of the world's top-ranked research universities. With more than 2,000 scientists, engineers, support professionals and students, GTRI helps solve the most difficult problems facing government and industry across the nation and around the world.

GTRI's $370-million-per-year research program is organized into three major areas: (1) electronics, optics and systems, (2) information and cyber sciences, and (3) sensors and intelligent systems. In support of those areas, GTRI operates eight research laboratories located on Georgia Tech's main campus in midtown Atlanta, and at the Cobb County Research Facility north of Atlanta. In addition, GTRI serves its customers through 18 field offices located around the United States. GTRI is a Department of Defense University Affiliated Research Center (UARC).

This report contains examples of GTRI's achievements in these mission areas listed below, as well as notable facts and figures from the 2015 and 2016 fiscal years.

Established Mission Areas

- Aerospace Systems
- Agricultural Systems
- Air and Missile Defense
- Robotics and Autonomous Systems
- Command and Control (C2) and Decision Support Systems
- Communications and Networked Systems
- Complex Systems Engineering
- Cybersecurity
- Electronic Warfare
- Intelligence, Surveillance and Reconnaissance (ISR) and Tactical Systems
- Materials and Micro-Devices
- Radio Frequency (RF) and Electro-Optical/Infrared (EO/IR) Sensors
- Threat Systems and Platforms

Emerging Mission Areas

National Security:

- Quantum Systems
- Space Systems
- Undersea Systems

Commercial Domain:

- Commercial Cyber Security
- Energy Systems and Sustainability
- Health Informatics and Data Analytics
- Intelligent Ground Transportation and Smart Cities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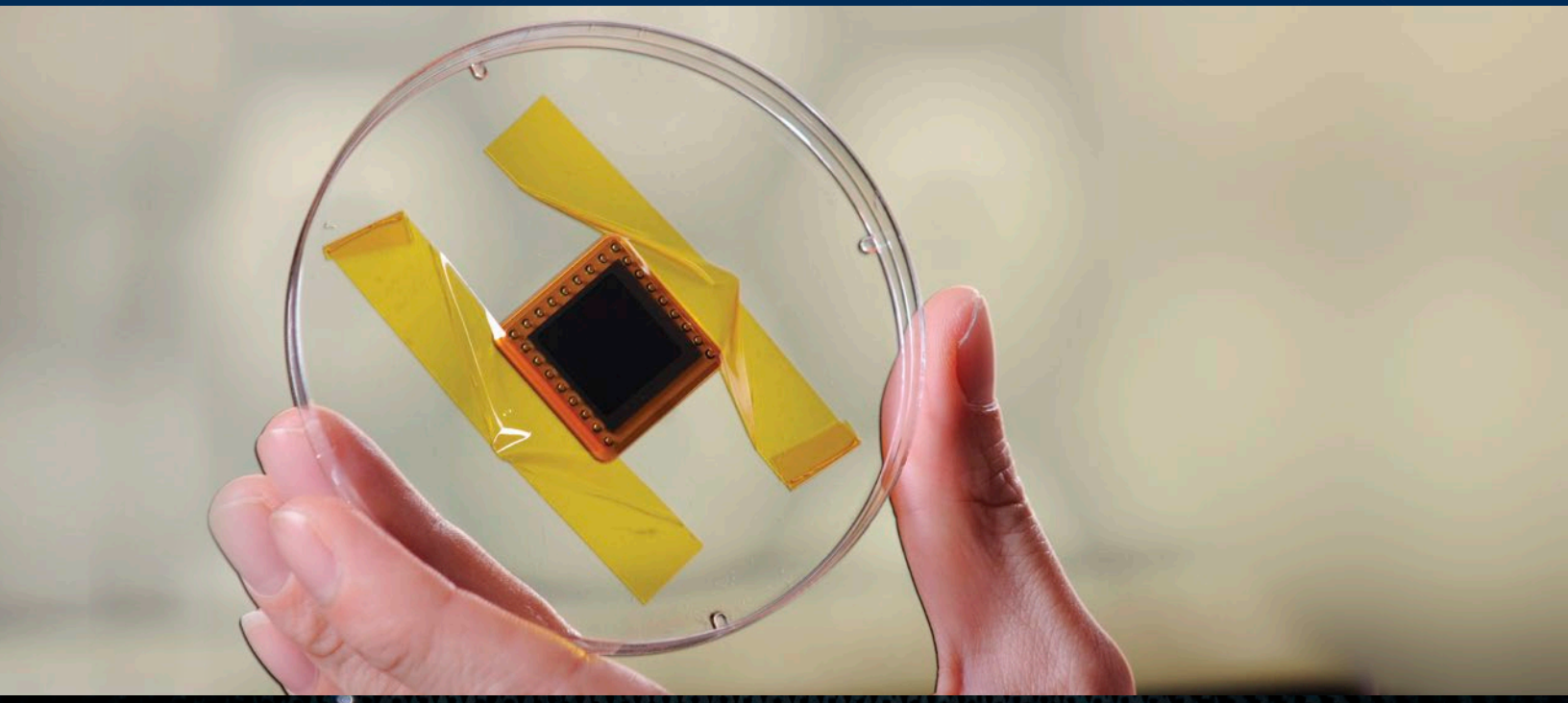
Georgia Tech Research Institute


TECH

OUR ORGANIZATION

ELECTRONICS, OPTICS & SYSTEMS



TOP: This photo shows a solar cell produced for space testing of new types of photovoltaic cell materials aboard the International Space Station.
BOTTOM: GTRI's Josh Bosse supports F-16 radar warning receiver integration testing at the Eglin AFB JPRIMES Anechoic Facility.

DIRECTORATE


Joe Brooks


Barry Bullard


Ken Kaminski


Gisele Bennett

GTRI researchers Heyward Adams, Andrew Hardin and Greg Bishop examine Internet of Things devices whose output can be integrated using GTRI's new FUSE software.

In the Electronics, Optics and Systems Directorate, 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, avionics, missile defense, soldier systems, health care and related areas. Three laboratories support this research:

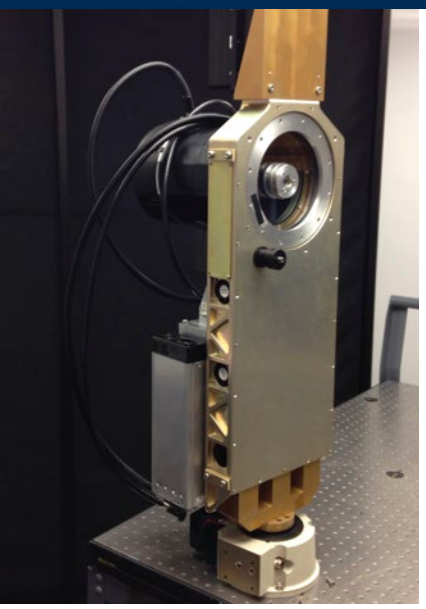
The **Applied Systems Laboratory (ASL)**, centered in Huntsville, Ala., conducts applied research focused on ground-based air and missile defense and rotary-wing aviation systems. Activities include system-of-systems and family-of-systems interoperability, fire control and command and control, system modeling and simulation, hardware-in-the loop and software-in-the loop testing, and critical safety software development and engineering.

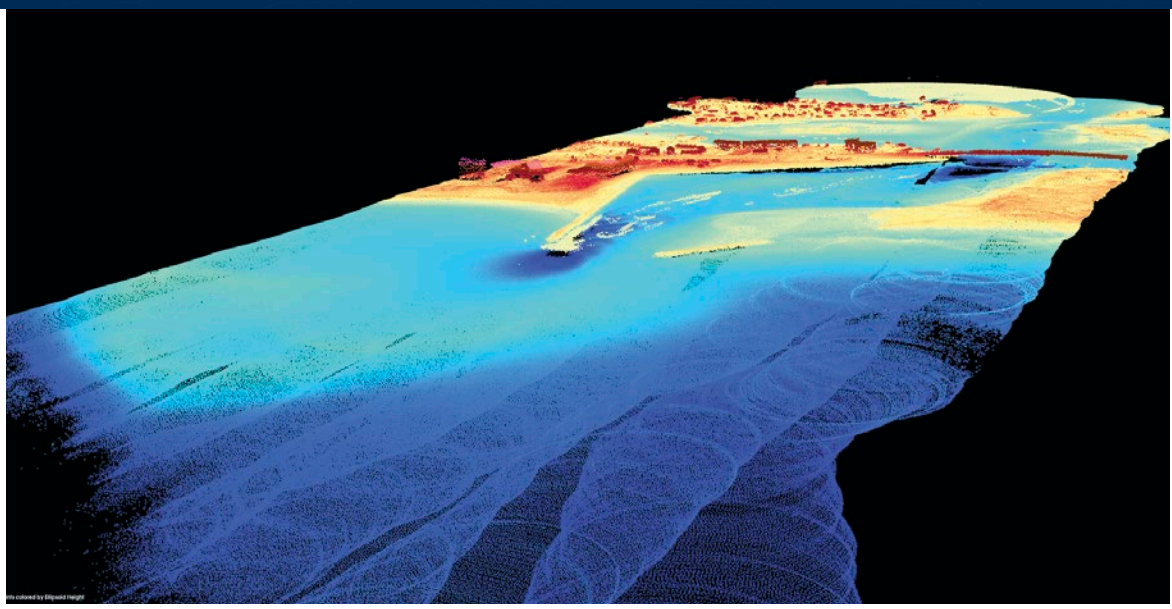
The **Electronic Systems Laboratory (ELSYS)** employs an end-to-end approach for developing electronic warfare and other electronic systems solutions. ELSYS systems engineering programs provide methodologies, tools, education, and leadership to support acquisition and life-cycle sustainment. The laboratory works in the early acquisition phase to help decision makers optimize the design trade space for a spectrum of DoD systems. An integral part of systems engineering is the human component. The lab's human systems research supports U.S. government agency needs, industrial product usability and accessibility evaluation, and workplace health and safety programs. ELSYS provides electronic warfare analysis, technology development, test and evaluation, support equipment, software, and integration to solve complex survivability problems in real-world applications. ELSYS provides avionics systems integration to include data fusion of multi-spectral electronic warfare systems, open systems standards development and piloting, and defensive suite integration.

The **Electro-Optical Systems Laboratory (EOSL)** leads GTRI's technology development in areas of electro-optical sensors, imaging components and systems, active electro-optic systems, and modeling, simulation, and analysis across the spectrum. EOSL applies technology solutions across the electronic warfare and intelligence surveillance and reconnaissance (ISR) mission areas. The lab also has programs leveraging its capability targeted to emergency response and other security applications.

OUR ORGANIZATION

ELECTRONICS, OPTICS & SYSTEMS





GTRI is designing and building a high-performance airborne bathymetric LIDAR that will be used for hydrographic surveying and environmental monitoring applications. The new LIDAR is half the size of existing systems and can produce data in near real-time.

Following are examples of GTRI research in electronics, optics and systems:

- GTRI is participating in the U.S. Army Integrated Air and Missile Defense Battle Command System (IBCS) program, aimed at integrating many existing air- and missile-defense weapon systems seamlessly into a single network through the use of advanced adaptors. This technology would let battalion command and control centers interact more effectively with diverse, widely distributed weapons systems, providing better situational awareness and battlefield control.

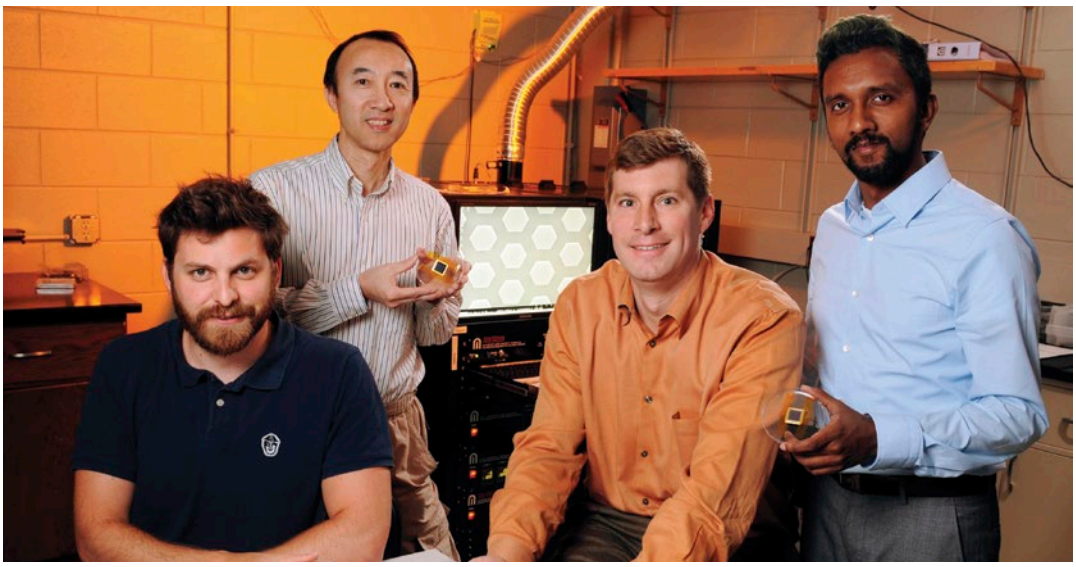
- With sponsorship from the U.S. Army's Research Development and Engineering Command, GTRI is providing an A/B Interface Test Tool (ABITT) that supports development of the crucial network component. Several defense contractors are participating in IBCS, including Northrop Grumman, Raytheon and Lockheed Martin, and GTRI is supporting all participants by analyzing network traffic between major hardware components and by simulating adaptors that are still being developed.

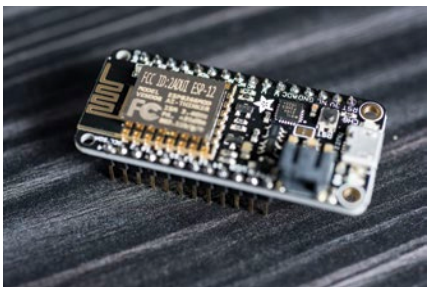
- A flexible data fusion service is enhancing the usability of the fast-growing Internet of Things (IoT). The FUSE software system helps standardize the largely unstandardized IoT world, using a generic communications platform that readily integrates data streams from real-world sensors into cohesive, human-readable information. The FUSE framework facilitates real-time data acquisition by letting users subscribe to webpages, APIs and other streaming-data sources that employ a multitude of protocols and modalities. FUSE also provides users with online forms that let them define the sources they need, gathers incoming raw data according to user specifications, and displays processed data via an interactive data visualization, exploration and analysis dashboard.

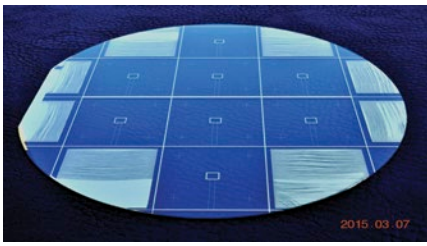
- GTRI is using cutting-edge photonics technology to extend U.S. electronic warfare (EW) capabilities. Optical approaches provide increased frequency coverage, superior electromagnetic interference (EMI) performance and unique signal-processing techniques, along with reduced size, weight and power (SWaP). Applying telecom technologies to EW needs, a GTRI team has developed optical transceivers that interface readily with existing digital or RF systems. Employing novel photonic integrated circuits (PICs), researchers are building ruggedized packages with increased flexibility and performance for existing and next-generation systems.

- GTRI's largest unit, the Electronic Systems Laboratory (ELSYS), is now fully certified under the ISO 9001 international quality management systems standard, which

DIRECTORATE







LEFT: A GTRI research team developed textured thin film photovoltaic devices based on earth-abundant materials. The devices were recently delivered to the International Space Station for testing. Shown are Stephan Turano, Hunter Chan, Jud Ready and Kavin Manickaraj. **RIGHT TOP:** Flexible, generic data-fusion software known as FUSE simplifies interacting with Internet of Things sensor networks. **RIGHT BOTTOM:** GTRI is using cutting-edge photonics technology in electronic warfare applications to provide such advantages as increased frequency coverage and superior electromagnetic interference performance.

is widely followed in industry. An official certification group has examined ELSYS activities and determined that the unit is following best practices regarding processes and procedures and conforming to ISO 9001 requirements. A two-year effort to demonstrate compliance with the standard culminated in interviews by certification officials with approximately 130 researchers. The laboratory's ISO 9001 status will be reviewed annually to ensure ongoing compliance.

- A novel three-dimensional solar cell design developed at GTRI is receiving its first space testing aboard the International Space Station. An experimental module containing 18 test cells was launched to the ISS and installed on the exterior of the station to study the cells' performance and their ability to withstand the rigors of space. In addition to testing the three-dimensional format, the module will also study a low-cost copper-zinc-tin-sulfide (CZTS) solar cell formulation. Built by coating miniature carbon nanotube "towers" with a photo-absorber that captures sunlight from all angles, the 3-D cells could boost the amount of power obtained from the small surface areas many spacecraft have.

- GTRI is designing and building a prototype high-performance real time airborne bathymetric LIDAR for an industry client. This new LIDAR will be used for hydrographic surveying and environmental monitoring applications and will produce data in near real time. The new system will be half the size of current airborne LIDARs, making it capable of use on mid-sized unmanned aerial vehicles (UAVs). The system uses high-power computing to gather and transmit data, producing undersea and land imagery with much greater speed and efficiency than current systems. An earlier prototype was tested on an airborne platform.

- GTRI is using collaborative modeling tools and trade-study approaches to tackle military design challenges. For the U.S. Army Corps of Engineers, researchers developed the Engineered Resilient Systems (ERS) Tradespace to help design defense equipment for maximum future usability. ERS uses web-based collaborative systems engineering and tradespace tools to identify the best combinations of adaptability, longevity and cost-effectiveness. For the U.S. Navy, GTRI is employing novel set-based design approaches to support capability concepts aimed at ensuring maximum design flexibility for the development of undersea command and control and unmanned underwater vehicles.

OUR ORGANIZATION

INFORMATION & CYBER SCIENCES

John Pyles, a GTRI principal research scientist, is shown with some of the components of FalconView. Originally developed for the Air National Guard, the program recently marked its 20th anniversary.

In the Information and Cyber Sciences Directorate, 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.

The **Cyber Technology and Information Security Laboratory (CTISL)** conducts applied research on cyber threats and countermeasures, secure multi-level information sharing, resilient command and control network architectures, reverse engineering, asymmetric operations and exploitation, high performance computing, and data analytics. Researchers develop and apply technologies in computing, network architectures, signal and protocol analysis, network forensics, malware analysis, open source threat information collection and correlation, insider threat detection and mitigation, hardware and software reverse engineering, and advanced analytics.

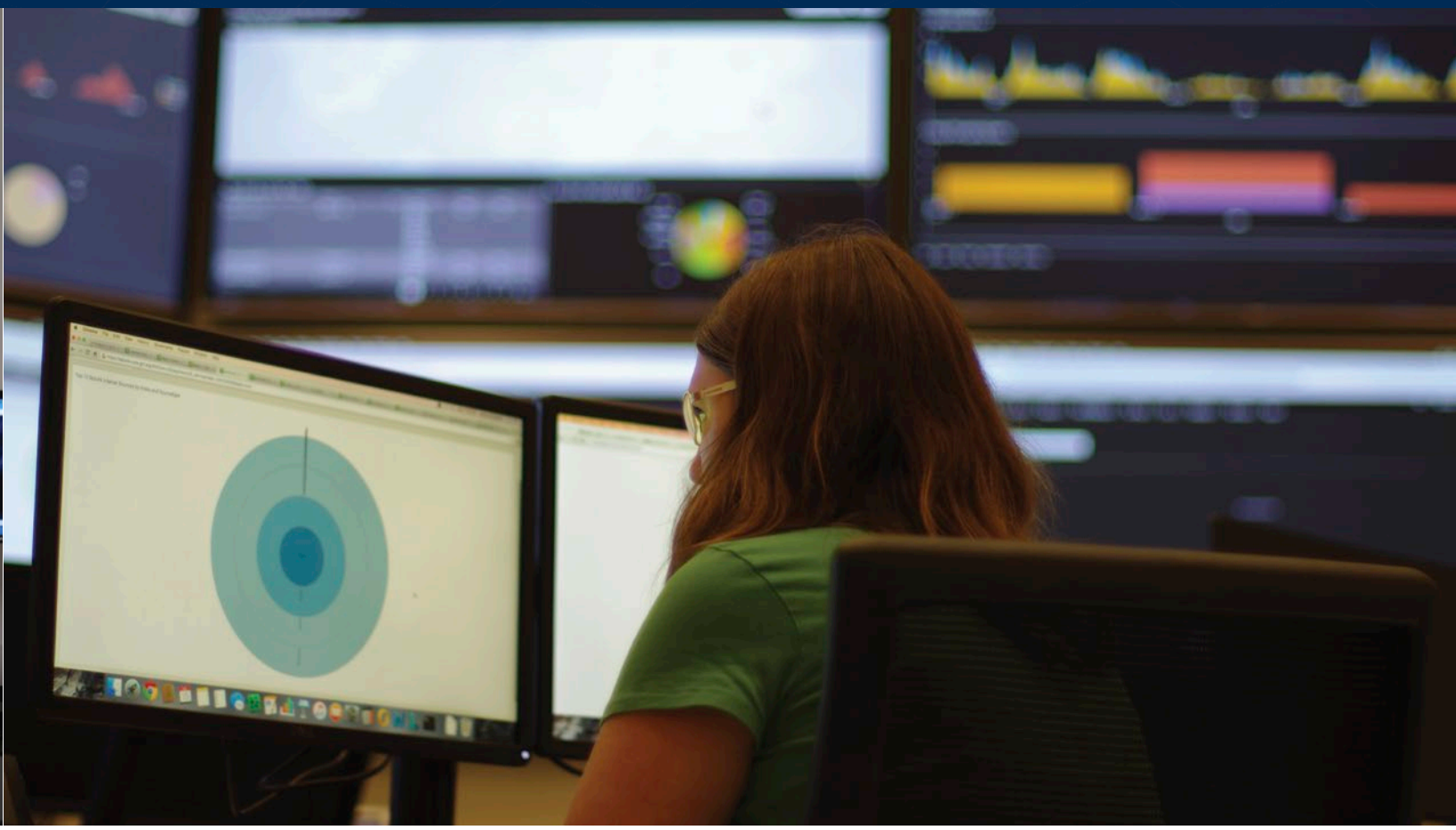
The **Information and Communications Laboratory (ICL)** conducts research that solves complex problems in areas of computer science, information technology, communications, networking, and socio-technical systems. Research for public and private clients supports national security; emergency response; integration of health care systems; interoperability and security of interconnected systems; education and learning; technology strategy, planning, and decision support; development of public policy; and commercial product realization.

DIRECTORATE


Bo Rotoloni


Andrew Howard


Jeff Evans



Researchers at GTRI are developing techniques to protect a broad range of systems against attack, including organization networks and Internet of Things devices.

- GTRI researchers are developing insider threat-detection systems that help protect organizations by monitoring computer networks for abnormal activity. These software products are designed to function seamlessly within operating domains and network monitoring software that customers typically use. Initiatives include (1) Layered Ensemble Anomaly Detection (LEAD) which interfaces with commercial network monitoring software to scan data for anomalous activity; (2) Threat Explorer, a software implementation that safeguards important documents by actively tracking factors including the number and sensitivity of the documents each individual can access, and (3) rule-based anomaly detection software that monitors for unusual behavior by IP address.

- GTRI researchers recently celebrated the 20th anniversary of FalconView®, first developed as a flight planning software system for the U.S. Air National Guard. The program now has more than 80,000 users, and it has been expanded to provide a broad range of mission planning, mapping and surveillance tasks. The core software allows aircrews to visualize digital maps and imagery in the context of their mission, both on the ground and in the air. In addition to topographical information, the system displays friendly and enemy positions, threats, tower and power line obstructions, as well as other rapidly changing information such as weather.

- An estimated 15 billion physical objects use the Internet to exchange data, a system known as the Internet of Things (IoT) that includes everything from home automation to embedded controllers. GTRI researchers are working to secure these embedded controllers, which cannot be protected like traditional computing systems. Strategies include development of novel

INFORMATION & CYBER SCIENCES

inspection tools, and techniques to determine how trustworthy embedded controllers might be realized, whether or not anything malicious has been inserted in their design.

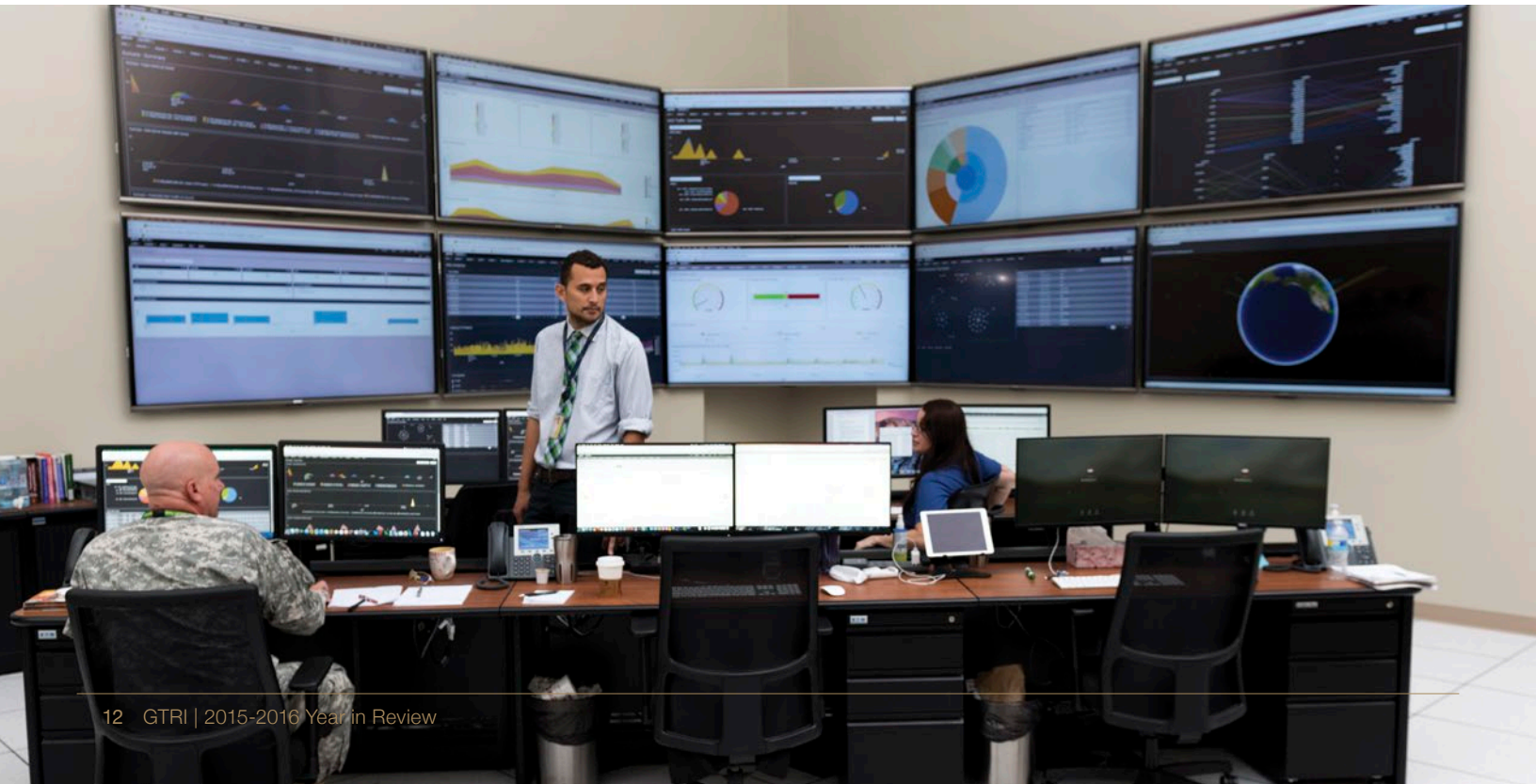
- In collaboration with Virginia Tech, GTRI has developed an architecture that provides process resilience against cyberattacks on physical targets. Known as Trustworthy Autonomic Interface Guardian Architecture (TAIGA), the design ensures stability regardless of what else may be happening within a computational system, taking a proactive approach to security by building in integrity from the beginning.

- Petabytes of digital information are generated daily by such sources as social media, surveillance sensors and advanced research instruments. Finding useful information within this information is challenging. Graph analysis is a prime tool for finding those needles in the data haystack, and GTRI researchers are bringing graph analytics to bear on a range of data-related challenges using a Georgia Tech-developed framework called STINGER, built specifically to tackle dynamic, ever-changing applications such as social networks, Internet traffic and malware analysis.

- "Going viral" may have taken longer in the 19th century, but the principle was much the same as it is today. Historians from the University of Georgia worked with GTRI computer scientists to develop an application that searches a database of 10 million newspaper pages to track how ideas moved across the United States before the advent of television and the Internet. The project, known as U.S. News Map, is helping researchers see history with spatial information that had not been available before.

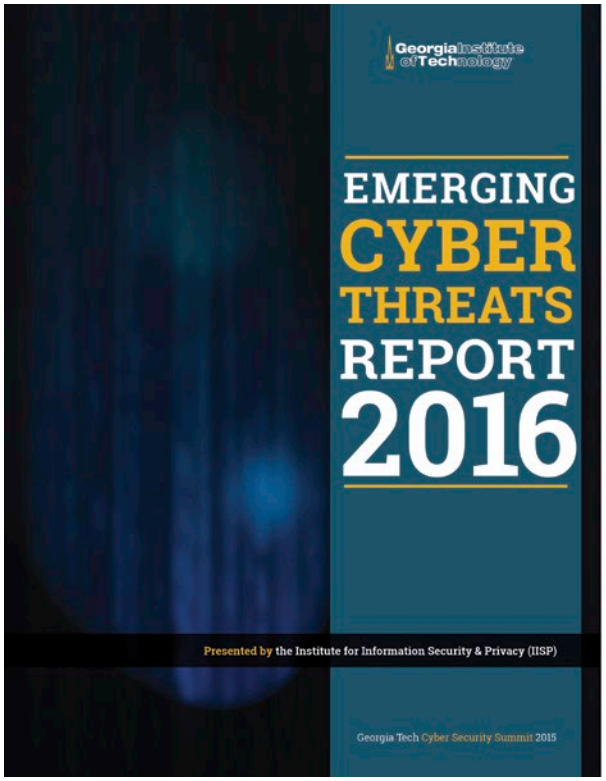
- A new analytics framework might soon help businesses monitor massive amounts of data in a user-friendly way. Developed by GTRI, Diamond Eye is a platform for one-stop data analytics. The platform enables data ingestion, processing and visualization in a single package, and is able to adapt to new data sources, new analytics or new visualizations. The system was

GTRI conducts applied research on cyber threats and countermeasures, secure multi-level information sharing, resilient command and control network architectures and related areas of information science.



designed to help users answer historical and real-time questions with their data. It can also provide situational and predictive results, using information about the past to help predict future conditions. Development of a flexible application program interface (API) helped make Diamond Eye user friendly.

- The "2016 Emerging Cyber Threats Report" warned about the privacy tug-of-war between individuals and organizations, the cyberattack surface created by the exponential growth in the Internet of Things, the lack of highly trained security workers as the digital economy continues to grow, and the continuing threat of cyber espionage. The topics are discussed at length in the report, which reflects the views of nearly two dozen cybersecurity experts from Georgia Tech, business, government and defense. Academia, industry and government must work together in bold new ways to address the grand challenges of cybersecurity, noted the report, which is published by the Institute for Information Security & Privacy (IISP) and GTRI.



RIGHT: Each year Georgia Tech compiles its "Emerging Cyber Threats Report" on top issues expected to affect cybersecurity. **BELOW:** Research Scientist Trevor Goodyear shows features of U.S. News Map, an application that searches a database of more than 10 million newspaper pages that is helping researchers see history with spatial information that hadn't been available before.

OUR ORGANIZATION

SENSORS & INTELLIGENT SYSTEMS

The Low-Cost UAV Swarming Technology (LOCUST) project is developing UAVs to autonomously overwhelm an adversary. GTRI has developed autonomy technology able to control a swarm of 30 UAVs.

In the Sensors and Intelligent Systems Directorate, GTRI conducts basic and applied research and builds advanced prototypes relating to air and missile defense; intelligence, surveillance, and reconnaissance; advanced electronic warfare; autonomous systems; threat systems exploitation, characterization, and simulation; and quantum information systems. Areas of emphasis include antenna technology, radar, signals intelligence, electromagnetic effects, electronic attack and protection, unmanned and autonomous payloads and platforms, quantum computing, sensor exploitation and signal processing, foreign systems analysis and material exploitation, underwater sensors, and transportation and related systems. Physics-based modeling and simulation and analysis is also a major work area. Sponsors include Department of Defense agencies, along with intelligence, homeland security, industry and other customers.

The **Advanced Concepts Laboratory (ACL)** identifies and transitions advances in basic 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 to prove new technologies and concepts.

The **Aerospace, Transportation and Advanced Systems Laboratory (ATAS)** develops advanced technologies and systems from concept to prototype. Included are system simulations and test and evaluations related to threat radars, missiles, air and ground vehicles, autonomous systems, transportation applications, power and energy systems, and food processing technologies.

The **Sensors and Electromagnetic Applications Laboratory (SEAL)** conducts research in intelligence, surveillance, and reconnaissance (ISR); air and missile defense; foreign material exploitation and electromagnetic systems; and electronic attack/electronic protection. SEAL investigates and develops radio/microwave frequency sensor systems with particular emphasis on radar systems engineering, electronics intelligence, communications intelligence, measurements intelligence, electromagnetic environmental effects, radar system performance modeling and simulation, advanced signal and array processing, sensor fusion and antenna technology.

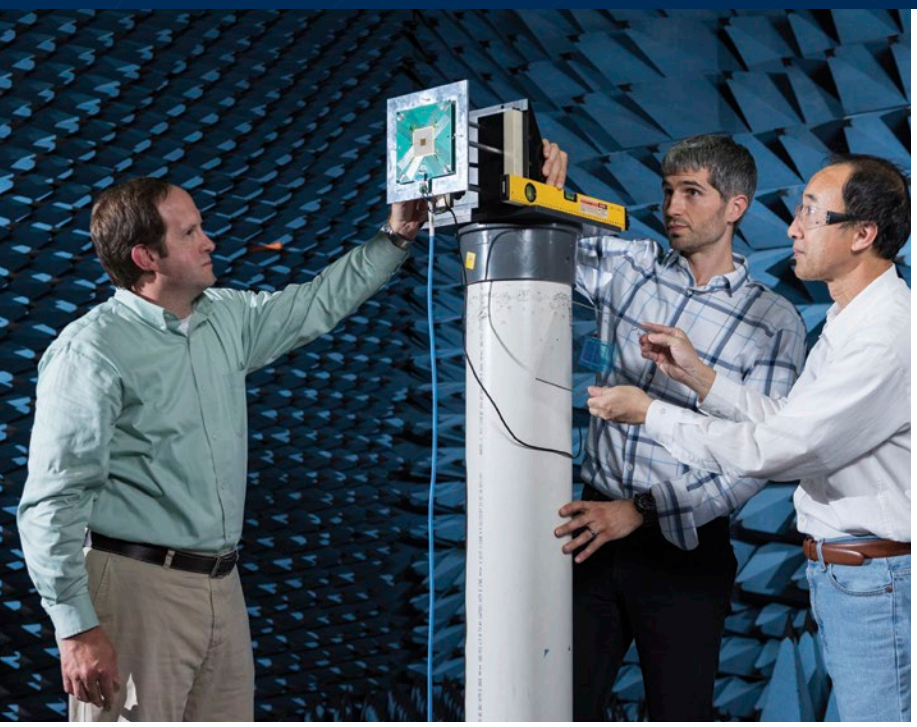
DIRECTORATE


William Melvin


Mark Mitchell


Rusty Roberts


Mel Belcher



LEFT: GTRI researchers are developing an innovative phased-array design that will allow each antenna element to be reconfigured via software to perform a variety of different tasks. The work is part of a DARPA program aimed at speeding development of phased-array systems. Shown are Todd Lee, Ryan Westafer and Hunter Chan. **RIGHT:** GTRI and CNN have been working together to study the issues affecting the use of unmanned aerial vehicles for newsgathering. Shown in CNN's World Headquarters are Greg Agvent, senior director of news operations for CNN, and Cliff Eckert, a GTRI senior research associate.

- The Low-Cost UAV Swarming Technology (LOCUST) project is developing swarming UAVs to autonomously overwhelm an adversary and to provide warfighters with a decisive tactical advantage. GTRI has developed autonomy technology that has controlled a swarm of 30 UAVs, where the aircraft are fully autonomous and collaborate to achieve mission objectives. GTRI's autonomy manages formation control, path planning and collision avoidance, incorporating techniques for task negotiation, fusion, inferencing and control.

- Modern phased-array antennas offer many advantages over older systems, but each phased array must be specially built for a single type of application. GTRI researchers are developing an innovative phased-array design in which each element contains more than a hundred interconnected radio-frequency switches that allow each element to be reconfigured via software to perform a variety of tasks. The work is part of Arrays at Commercial Timescales (ACT), a DARPA program aimed at speeding development times for phased-array systems.

- GTRI is tackling a challenging problem in radar technology: real-time detection of individuals walking or running. With sponsorship from the Air Force Research Laboratory, researchers are developing advanced signal processing algorithms that enable radar to collaborate on distinguishing humans in motion from other objects such as buildings, roads, vehicles or animals. Known as dismount technology, this capability could be of significant value for intelligence, surveillance and reconnaissance work, including border control, search-and-rescue missions, and military operations.

- To support research into airborne multi-sensor technologies, GTRI operates two TigerShark unmanned aerial systems for testing distributed systems. The UAVs have been flown and tested with a four-channel multi-mode radar that can be flown in monostatic and bistatic configurations. The military pedigree TigerShark aircraft have significant capabilities for flying payloads and supporting tactically significant missions. Other UAV payloads include four channel, wideband SIGINT, coherent jammers based on GTRI's Angry Kitten technology base, and an optical ball.

SENSORS & INTELLIGENT SYSTEMS

LEFT: Technicians prepare one of GTRI's TigerShark unmanned aerial systems for flight. The aircraft has two large payload bays that offer significant capabilities for supporting tactically significant missions. **RIGHT:** One of GTRI's two TigerShark unmanned aerial systems takes off during a test flight. The UAVs have been flown and tested with a four-channel multi-mode radar that can be flown in monostatic and bistatic configurations.

- GTRI is using its agile software development capabilities to support a military program known as Forward Processing, Exploitation, and Dissemination (FPED), which tests and evaluates intelligence, surveillance and reconnaissance (ISR) systems used to monitor military and security operations globally. Sponsored by the Air Force, this project includes monthly "Sprint" sessions that bring GTRI personnel together with other industry and military experts to evaluate each upgraded edition of the Air Force C2 ISR system before it is distributed to analysts at monitoring centers.

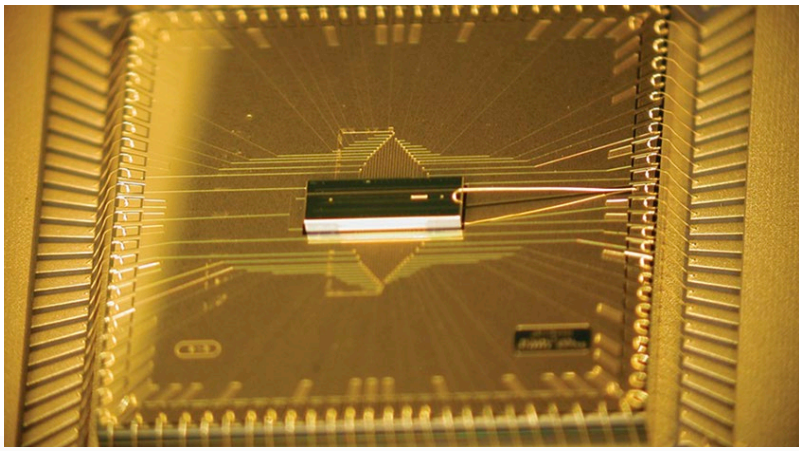
- Quantum computers are, in theory, capable of simulating the interactions of molecules at a level of detail far beyond the capabilities of even the largest supercomputers today. Such simulations could revolutionize chemistry, biology and materials science, but the development of quantum computers has been limited by the number of quantum bits, or qubits, that encode, store and access large amounts of data. Researchers from GTRI and Honeywell International have demonstrated a new device that allows more electrodes to be placed on a chip, an important step that could help increase qubit densities.

- GTRI researchers have worked with Atlanta-based CNN to study the use of unmanned aerial vehicles (UAVs) for newsgathering. In January 2015, CNN signed an agreement with the Federal Aviation Administration (FAA) to share the results of the research. The project examined both available unmanned systems and the procedures appropriate for using them in newsgathering. Beyond CNN, the results could be helpful in applications such as railroad and agricultural inspections.

- For vessels operating at sea, avoiding collisions is a basic operational requirement. When those vessels become highly autonomous, collision avoidance must be incorporated into complex autonomy algorithms that must be thoroughly tested before the vessels enter the water. GTRI researchers have created an assessment tool for systematically stimulating and

Researchers at GTRI have created an assessment tool called AVIA for systematically stimulating and testing the logic of fully autonomous systems while they are under development. Research Scientist Tara Madden, shown with an AVIA screen, led development of the system's user interface.

testing the logic of highly autonomous systems while they are under development. Known as Autonomy Validation, Introspection, and Assessment (AVIA), the tool was developed with support from the Defense Advanced Research Projects Agency (DARPA) to assess the autonomy logic of unmanned systems, and specifically for a technology demonstration vessel developed in DARPA's Anti-Submarine Warfare Continuous Trail Unmanned Vessel (ACTUV) program. AVIA stimulates the actual autonomy logic of the unmanned vessel to study how an autonomous vessel would interact with a dozen or more other vessels at sea. AVIA could also be useful for evaluating highly autonomous systems designed to operate on the ground, in the air, or even in space.



Researchers from GTRI and Honeywell International have demonstrated a new technique that allows more electrodes to be placed on a quantum computing device – an important step that could help increase qubit densities.

TECHNOLOGY & INNOVATION

GTRI's eight laboratories each has a lab chief scientist. Shown are Michael Farrell (CTISL), Mark Smith (SEAL), Margaret Loper (ICL), Lora Weiss (GTRI Chief Scientist), Erica Briscoe (ATAS), Alexa Harter (ACL), Andy Register (ELSYS), and Darrell Lamm (EOSL). Not pictured is Patrick Dowdy (ASL).

GTRI's chief scientist provides leadership to maintain the institute's scientific and technological preeminence through its independent research and development (IRAD) projects, the appointment of GTRI Fellows, interactions across a network of laboratory-based chief scientists, Georgia Tech's teaching fellowships, and publication of an internal IRAD journal designed to share information about innovations that may advance capabilities of interest to key GTRI sponsors.

Independent Research & Development (IRAD)

The purpose of GTRI's IRAD investment is to develop and advance research that addresses national security and global challenges. Early-stage projects funded by the program 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.

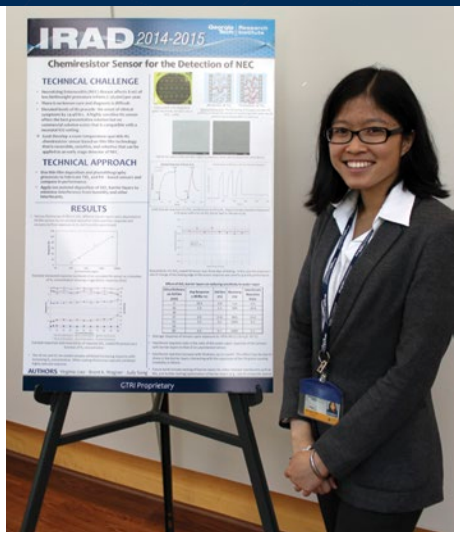
Strategic initiatives develop significant capabilities in areas of national security and global importance. They substantially advance GTRI's existing research strengths, and they can be bold forays into somewhat uncharted territory for which GTRI has the technical acumen.

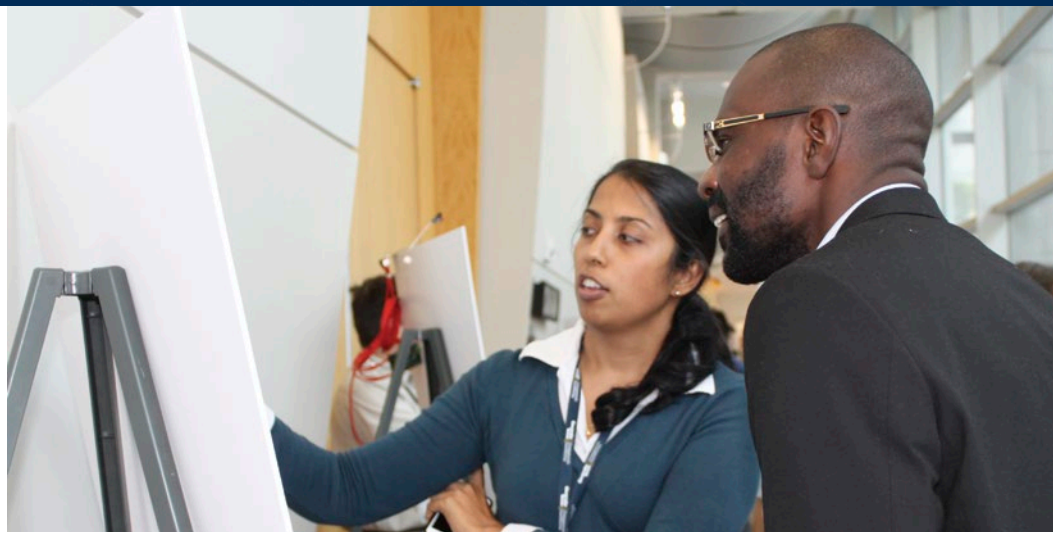
Tactical and discretionary initiatives are funded in response to a known business area with known sponsors, to address a technology gap, or to get ahead of a potential opportunity. They are more high-risk/high-payoff, they may be quick-reaction or purely exploratory.

Hives Initiatives explore disruption created by the convergence of commodity technologies with global trends. They explore the co-evolution of technology with concept of operation (CONOPS), and they seek to 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 of GTRI based on a competitive review process that evaluates technical achievements and alignment with critical GTRI research. GTRI Fellows are technically renowned and their research is significantly relevant to the GTRI strategy.





GTRI researchers present posters annually regarding their independent research and development projects. GTRI's IRAD investment is intended to expand capability and sustain a competitive position in critical mission areas, as well as foster exploration and accelerate entry into new areas of interest to sponsors.

Georgia Tech Teaching Fellows

As an integral part of the Georgia Institute of Technology, GTRI supports the educational mission of the overall organization through teaching courses in academic departments and through Georgia Tech's Professional Education program. The GTRI chief scientist selects top researchers for participation in teaching opportunities through a competitive process administered through Georgia Tech's Executive Vice President for Research.

GTRI Chief Scientist

Since 2014, Lora Weiss has served as chief scientist. Weiss is a Regents Researcher for the University System of Georgia and the chief scientist of the Georgia Tech Research Institute (GTRI). As chief scientist, she is responsible for the portfolio of independent research and development investments at GTRI. Weiss' personal research is on the design, development, and implementation of technologies for unmanned and autonomous systems. For more than 25 years, she has been responsible for advancing capabilities of unmanned systems spanning the domains of air, ground, sea surface, and undersea. 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. She was on the technical advisory board of the National Robotics Technology Consortium, and she currently chairs the international ASTM Committee on Unmanned Maritime Vehicle Autonomy and Control. Weiss was a member of the steering committee for Information Science and Technology Study Group for DARPA, and she recently supported the National Academy of Sciences Naval Studies Board on mainstreaming unmanned underwater vehicles into the Navy. She received her B.S. in mathematics from Boston University magna cum laude, an M.S. in mathematics from the University of California Los Angeles, and a Ph.D. in acoustics from Pennsylvania State University.

GEORGIA TECH COLLABORATIONS

GTRI principal research engineer Mick West, graduate student Jacob Buffo of the Georgia Tech School of Earth and Atmospheric Sciences, and undergraduate Matthew Meister of the Georgia Tech School of Mechanical Engineering, handle the 210-pound Icefin underwater vehicle. Icefin was designed and built by a team of researchers from GTRI and Georgia Tech's School of Earth and Atmospheric Sciences to explore the vast Ross Ice Shelf in Antarctica.

GTRI is an integral part of the Georgia Institute of Technology, 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 customers.

U.S. News & World Report ranks Georgia Tech seventh overall among the nation's top public universities, and its undergraduate engineering programs are ranked fifth. Georgia Tech has nearly 2,000 academic and research faculty, and more than 25,000 graduate and undergraduate students. The Georgia Tech research program totaled $785 million for 2015.

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. In 2015, 544 Georgia Tech 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 fiscal year 2015, GTRI had 10 research faculty enrolled in its teaching fellows program, and a dozen research faculty who had joint appointments in academic colleges. Researchers taught more than 150 professional education courses in such areas as radar, aerospace design, acoustics, electronic systems and robotics.

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

GTRI is not simply a part of Georgia Tech: GTRI is Georgia Tech.

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

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

- The Institute for Internet Security and Privacy (IISP): Co-directed by Bo Rotoloni, GTRI Deputy Director of Information and Cyber Sciences;
- The Institute for People and Technology (IPaT): Deputy Director, Leigh McCook, Information and Communications Laboratory principal research associate; and
- Industry for the Institute for Robotics and Intelligent Machines: Associate Director, Gary McMurray, Food Processing Technology Division Chief.

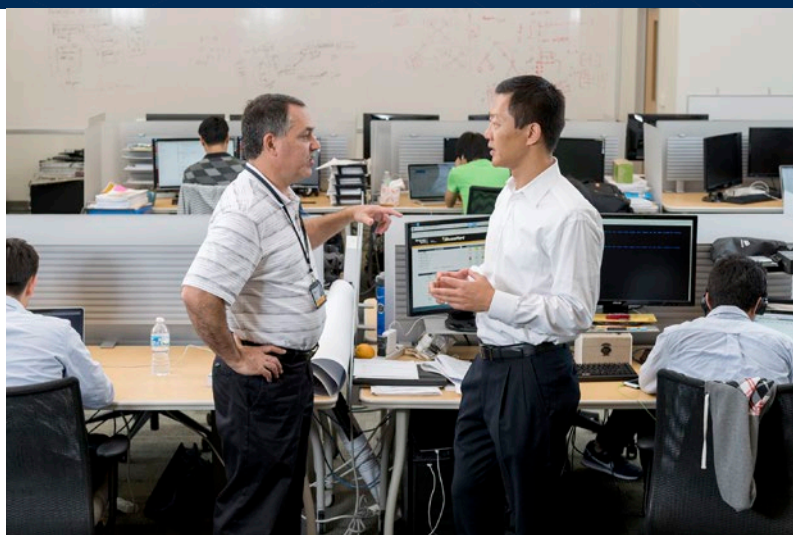
GTRI's researchers work with hundreds of Georgia Tech graduate and undergraduate students to develop the next generation of scientists and engineers.

GTRI researchers work with Georgia Tech's undergraduate students' Capstone Design projects, which are real-world, open-ended and interdisciplinary challenges.

GTRI researchers collaborate with Georgia Tech's academic units in many vertically integrated projects (VIPs), including the following:

- Configurable Computing and Embedded Systems;
- Martian Advanced Renewable Systems (MARS);
- GTRI Agricultural Robots;
- Aquabots: Maritime Robotics;
- Health Informatics on FHIR; and
- Chip Scale Power & Energy.

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.



LEFT: Georgia Tech has formed the Institute for Information Security & Privacy to bring together cyber research activities. It is led by Co-Directors Bo Rotoloni of GTRI and Wenke Lee of Georgia Tech's College of Computing.

Number of Georgia Tech students working at GTRI — **544**

Number of courses and certificate programs taught by GTRI — **177**

Number of GTRI/Georgia Tech joint appointments — **12**

Number of GTRI teaching fellows — **10**

Number of GTRI research faculty participating as advisors in capstone projects — **9**

Number of vertically integrated projects (projects that unite undergraduate students with graduate students and faculty research members in a team-based context) — **6**

Number of Georgia Tech Interdisciplinary Research Institutes with GTRI researchers in leadership positions — **4**

DIVERSITY, OUTREACH & EDUCATION

GTRI Diversity Consultant Shatanese Reese and GTRI Director Andrew Gerber with Georgia Tech students employed by GTRI.

Committed to Diversity

GTRI's commitment to diversity and inclusion is absolute. Respect for differences is a key part of our culture and a vital element of our success. We believe excellence is achieved by synthesizing contributions from people of varied ideas, backgrounds and perspectives.

We create and strengthen our diverse workforce through student outreach, collaboration with Georgia Tech campus entities, national professional organizations and diversity-related career fairs. This approach allows us to attract, develop and retain the very best talent available. This commitment ensures that we forge the relationships necessary to continue our dynamic growth.

As part of Georgia Tech, GTRI works closely with the Office of Institute Diversity and Student Diversity Programs embracing diversity and inclusion as key parts of the Georgia Tech Strategic Plan.

Highlights:

- Five deserving female and underrepresented minority Georgia Tech students were each awarded a $10,000 scholarship in 2015 from GTRI. Given annually, the scholarship is envisioned as a way to strengthen the ties between students on campus and GTRI, showcasing GTRI as an organization invested in developing their careers.
- Through the Talent Management Department, GTRI actively promotes collaboration with campus initiatives, such as Georgia Tech's Employee Resource Groups, diversity ambassadors, diversity symposia, invited speakers and special events. Additionally, TMD attends and supports diversity-specific career fairs.
- In fiscal years 2015 and 2016, GTRI hosted several diversity symposia, including the Symposium on Workforce Demographics and Implicit Associations, and continued its Women's Book Club.
- In conjunction with Georgia Tech, GTRI manages the Historically Black Colleges & Universities/Minority Institutions Outreach Initiative, which works to pair researchers and faculty members from Georgia Tech with potential partners from minority institutions.

Commencement ceremony for graduates of Georgia Tech's Professional Master's in Applied Systems Engineering (PMASE).

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 more than 97 defense technology courses and 57 safety and health courses, as well as 23 professional certificates offered in both disciplines. Georgia Tech's Professional Master's in Applied Systems Engineering (PMASE) recently graduated 109 students with another 53 currently enrolled. In the last fiscal year, GTRI's professional education programs had 4,673 students.

Engaging Students through STEM Outreach

STEM@GTRI's strategy for science, technology, engineering and mathematics (STEM) education outreach is an enterprise-wide approach that works to inspire, engage and impact Georgia educators and students by providing access to experts in STEM fields.

GTRI strives to engage students with real-world science and research, improve academic performance in STEM subjects, encourage students to pursue educational and career opportunities in these areas, as well as provide materials for teachers to strengthen their STEM-related curriculum.

STEM@GTRI participated in multiple areas of activity over the past few years, including partnerships with Atlanta Public Schools, Georgia Tech's Center for Education Integrating Science, Mathematics, and Computing (CEISMC), the Technology Association of Georgia Educational Collaborative (TAG-Ed), and Georgia Tech's Center for the Enhancement of Learning (CETL). In FY15 and FY16 STEM@GTRI reached more than 10,000 students and 500 teachers through various activities and events, some of which are highlighted below:

- Through a partnership with TAG-Ed, GTRI continues to host high school interns each summer in labs across the organization. Participation has steadily increased with 21 students participating in 2015 and 28 students in 2016. These students have the opportunity to be involved with a variety of projects, including working on a prototype situational awareness platform, participating in an intense robotics camp, as well as building working products via a rapid prototyping/engineering design lab.
- In April 2016, GTRI welcomed nearly 200 students to its Robotics Demo Day, where they could view and interact with six robot demonstrations. Researchers presented their studies, and robot demonstrations ranged from agile assembly assistance to working with poultry and agriculture.
- GTRI researchers served as advisers for students and teachers during the Small Fry to Go STEM program for pre-kindergarten to eighth-grade students. Small Fry to Go is a nationally recognized program where elementary students and teachers released nearly 2,000 rainbow trout fry that they had raised in the classroom into the Chattahoochee River in Georgia.
- GTRI collaborated with the U.S. Navy to host nine middle schools at the Georgia Tech Campus Recreation Center for the SeaPerch underwater remotely operated vehicles (ROV) competition in September 2015. Teams from the different schools included more than 140 students who completed a series of tasks and raced their vehicles in the Georgia Tech pool.

Metro Atlanta middle school students participate in the GTRI and Navy STEM Summit and SeaPerch Competition held at the Georgia Tech Campus Recreation Center.

For more information on STEM@GTRI activities, please visit gtri.gatech.edu/STEM.

2015-2016 GTRI BOOK AUTHORS

Nathan Adams (ELSYS), Lawrence Pihera (ELSYS) (chapter co-authors)

"Model Based Systems Engineering: Extracorporeal Membrane Oxygenation (ECMO) Therapy," *Modeling & Simulation in the Systems Engineering Life Cycle: Core Concepts and Accompanying Lectures, Series: Simulation Foundations, Methods and Applications*, Loper, M. (Ed.), New York: Springer, 2015.

Carlee Bishop (ELSYS) (chapter author)

"Systems Engineering Fundamentals," *Modeling & Simulation in the Systems Engineering Life Cycle: Core Concepts and Accompanying Lectures, Series: Simulation Foundations, Methods and Applications*, Loper, M. (Ed.), New York: Springer, 2015.

Erica Briscoe (ATAS), Scott Appling (ICL) (chapter authors)

"Social Network Derived Credibility," *Recommendation and Search in Social Networks, Lecture Notes on Social Networks (LNSN) Series*, Springer, 2015.

Tommer Ender (ELSYS), Santiago Balestrini-Robinson (ELSYS) (chapter co-authors)

"Surrogate Modeling," *Modeling & Simulation in the Systems Engineering Life Cycle: Core Concepts and Accompanying Lectures, Series: Simulation Foundations, Methods and Applications*, Loper, M. (Ed.), New York: Springer, 2015.

Tommer Ender (ELSYS), Daniel Browne (ELSYS) (chapter co-authors)

"Framework for Assessing Cost and Technology," *Modeling & Simulation in the Systems Engineering Life Cycle: Core Concepts and Accompanying Lectures, Series: Simulation Foundations, Methods and Applications*, Loper, M. (Ed.), New York: Springer, 2015.

Tommer Ender (ELSYS), Phillip West (EOSL), William Blair (SEAL), Paul Miceli (SEAL) (chapter co-authors)

"On Analysis of Ballistic Missile Defense Architecture through Surrogate Modeling and Simulation," *Modeling and Simulation Support for System of Systems Engineering Applications*, Rainey, L.; Tolk, A. (Eds.), Wiley Publishing, Inc., 2015.

Dennis Folds (ELSYS) (chapter author)

"Systems Engineering Perspective on Human Systems Integration," *American Psychological Association Handbook of Human Systems Integration*, Boehm-Davis, Durso, Lee (Eds.), American Psychological Association (APA), 2015.

"Human-in-the-Loop Simulation," *Modeling & Simulation in the Systems Engineering Life Cycle: Core Concepts and Accompanying Lectures, Series: Simulation Foundations, Methods and Applications*, Loper, M. (Ed.), New York: Springer, 2015.

Steve Gordon (ATAS) (chapter author)

"Design of Experiments," *Modeling & Simulation in the Systems Engineering Life Cycle: Core Concepts and Accompanying Lectures, Series: Simulation Foundations, Methods and Applications*, Loper, M. (Ed.), New York: Springer, 2015.

"Return on Investment Metrics for Funding Modeling and Simulation," *Modeling & Simulation in the Systems Engineering Life Cycle: Core Concepts and Accompanying Lectures, Series: Simulation Foundations, Methods and Applications*, Loper, M. (Ed.), New York: Springer, 2015.

Margaret Loper (ICL) (book editor and chapter author)

"The M&S Lifecycle Process," *Modeling & Simulation in the Systems Engineering Life Cycle: Core Concepts and Accompanying Lectures, Series: Simulation Foundations, Methods and Applications*, Loper, M. (Ed.), New York: Springer, 2015.

"Modeling Time," *Modeling & Simulation in the Systems Engineering Life Cycle: Core Concepts and Accompanying Lectures, Series: Simulation Foundations, Methods and Applications*, Loper, M. (Ed.), New York: Springer, 2015.

"Distributed Simulation & Architectures," *Modeling & Simulation in the Systems Engineering Life Cycle: Core Concepts and Accompanying Lectures, Series: Simulation Foundations, Methods and Applications*, Loper, M. (Ed.), New York: Springer, 2015.

Thomas McDermott (ELSYS) (chapter author)

"Systems Thinking," *Modeling & Simulation in the Systems Engineering Life Cycle: Core Concepts and Accompanying Lectures, Series: Simulation Foundations, Methods and Applications*, Loper, M. (Ed.), New York: Springer, 2015.

Christian Michelson (ELSYS) (chapter author)

"Issues Surrounding Communications with Micro Air Vehicles" *Handbook of Unmanned Aerial Vehicles*, Valavanis, Kimon P., Vachtsevanos, George J. (Eds.), Springer Publishing, 2014.

Stuart Michelson (ELSYS) (chapter author)

"Survey of the Human Centered Approach to Micro Air Vehicles," *Handbook of Unmanned Aerial Vehicles*, Valavanis, Kimon P., Vachtsevanos, George J. (Eds.), Springer Publishing, 2014.

Lawrence Pihera (ELSYS), Nathan Adams (ELSYS), Tommer Ender (ELSYS) (chapter co-authors)

"Medical Enhancements to Sustain Life during Extreme Trauma Care," *Modeling and Simulation Support for System of Systems Engineering Applications*, Rainey, L.; Tolk, A. (Eds.), Wiley Publishing, Inc., 2015.

Andy Register (ELSYS) (chapter author)

"Continuous Time Simulation," *Modeling & Simulation in the Systems Engineering Life Cycle: Core Concepts and Accompanying Lectures, Series: Simulation Foundations, Methods and Applications*, Loper, M. (Ed.), New York: Springer, 2015.

"Monte Carlo Analysis," *Modeling & Simulation in the Systems Engineering Life Cycle: Core Concepts and Accompanying Lectures, Series: Simulation Foundations, Methods and Applications*, Loper, M. (Ed.), New York: Springer, 2015.

Andy Register (ELSYS), Margaret Loper (ELSYS) (chapter co-authors)

"Introduction to M&S," *Modeling & Simulation in the Systems Engineering Life Cycle: Core Concepts and Accompanying Lectures, Series: Simulation Foundations, Methods and Applications*, Loper, M. (Ed.), New York: Springer, 2015.

Charles Turnitsa (ICL) (chapter author)

"Conceptual Modeling," *Modeling & Simulation in the Systems Engineering Life Cycle: Core Concepts and Accompanying Lectures, Series: Simulation Foundations, Methods and Applications*, Loper, M. (Ed.), New York: Springer, 2015.

Matt Weber and Frank Klucznik (ICL) (chapter co-authors)

"Improving Robotic and Autonomous Systems Information Interoperability: Standardizing Data Exchanges with XML," *Modeling and Simulation for Autonomous Systems*, Hodicky, J. (Ed.); Springer International Publishing, 2015.

Betty Whitaker (ICL) (chapter author)

"Modeling Behavior," *Modeling & Simulation in the Systems Engineering Life Cycle: Core Concepts and Accompanying Lectures, Series: Simulation Foundations, Methods and Applications*, Loper, M. (Ed.), New York: Springer, 2015.

"Agent Based Simulation," *Modeling & Simulation in the Systems Engineering Life Cycle: Core Concepts and Accompanying Lectures, Series: Simulation Foundations, Methods and Applications*, Loper, M. (Ed.), New York: Springer, 2015.

"System Dynamics Simulation," *Modeling & Simulation in the Systems Engineering Life Cycle: Core Concepts and Accompanying Lectures, Series: Simulation Foundations, Methods and Applications*, Loper, M. (Ed.), New York: Springer, 2015.

GTRI RECOGNITIONS

American Institute of Aeronautics & Astronautics (AIAA) Senior Member
David Alvord

Anti-Terrorism Accreditation Board Distinguished Service Award
Terry Culver

Association of Old Crows (AOC) Technology Hall of Fame Award
Linda Viney

Army Science Board
Gisele Bennett

Huntsville Association of Tech Societies 10th Annual Joseph C. Moquin Award
Eric Grigorian

IEEE Senior Members
Jeff Bean
Jacqueline Fairley
Sean Flanagan
Jennifer Geist
Jordan Gray
Ken Kaminsky
Greg Kiesel
Michael Kopp
Alvaro Marenco
James Marks
Alessio Medda
Allison Mercer
Nick Mulkey
Rafael Nevarez
Terry Ogle
Scott Silence
John Wilcher
Scott Wood
David Zurn

IEEE Region 3 Director's Choice Award
Jill Gostin

IEEE Region 3 Outstanding Engineer Award
Glenn Hopkins

IEEE Huntsville 2015 Professional of the Year
Eric Grigorian

IEEE Standards Association Emerging Technology Award
Stephen Balakirksy (as part of a team)

IEEE Atlanta Section Outstanding Engineer Award
Glenn Hopkins

IEEE AESS Nathanson Memorial Radar Award
Ryan Hersey

International Coordinating Group on Laser Atmospheric Studies (ICLAS) Service Recognition
Gary Gimmestad

2015 International Test & Evaluation Association (ITEA) President's Award
Steven "Flash" Gordon

National Classification Management Society (NCMS) Chapter Spotlight Award
Harriett Sheffield

National Classification Management Society (NCMS) Chapter Champion Award
Al Concord

National Training & Simulation Association (NTSA) Modeling and Simulation Award
FACT Team

Peachtree Roost Crow of the Year
Chris Ward

SPIE George W. Goddard Award
Grady Tuell

SPIE Senior Members
J. Chris James
Terence Haran

2015 Bronze Telly Award
GTRI Communications Team

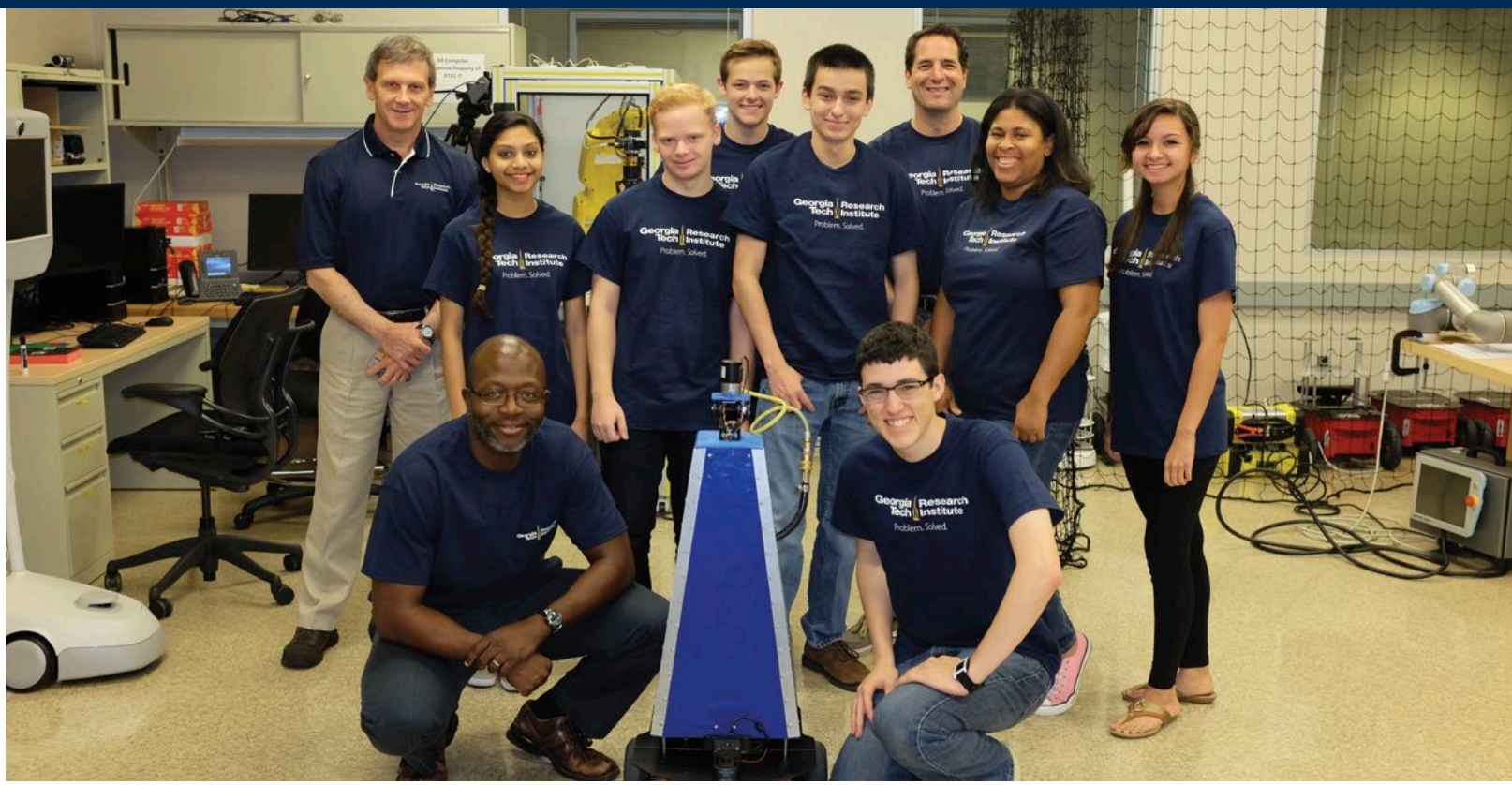
USAF Scientific Advisory Board
Bill Melvin

University System of Georgia (USG) Executive Leadership Institute
Joe Brooks

Women in Technology Woman of the Year in Technology
Leanne West

GTRI
Defense Security Service (DSS) Counterintelligence Program Award
E-Week Engineering Employer of the Year

FINANCIAL STATEMENT



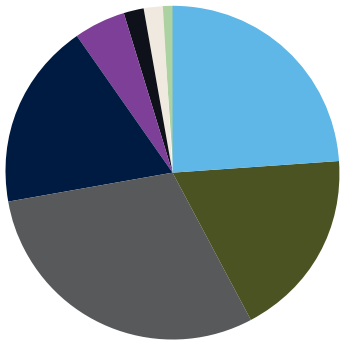
GTRI partnered with the Technology Association of Georgia Education Collaborative (TAG-Ed) to host summer interns. Under this program, high-school students and teachers were given the opportunity to interact with robotic hardware and software. They created a fun and educational water gun toting robot that was able to lock onto and follow a person while spraying them with water.

During the fiscal year that ended June 30, 2016, GTRI, a non-profit applied research and development organization, recorded revenue from contracts, grants, and other sources totaling $370 million, compared with $352 million for the previous fiscal year. Contract awards for the fiscal year reached $367 million, surpassing the previous year's total of $338 million.

OUR SPONSORS

Revenue from Contracts and Grants

Air Force	$89M
Army	$68M
Navy	$67M
Other DoD	$111M
Other Non-DoD Federal Agencies	$18M
State and Local Governments	$7M
Private (Universities, Businesses)	$6M
Other Revenues	$4M
Total:	$370 million



OUR LEADERSHIP

GTRI LEADERSHIP

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R&D LEADERSHIP

GTRI's eight research laboratories are organized into three research and development directorates. Complete laboratory descriptions and contact information are available at www.gtri.gatech.edu/labs.

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Mel Belcher
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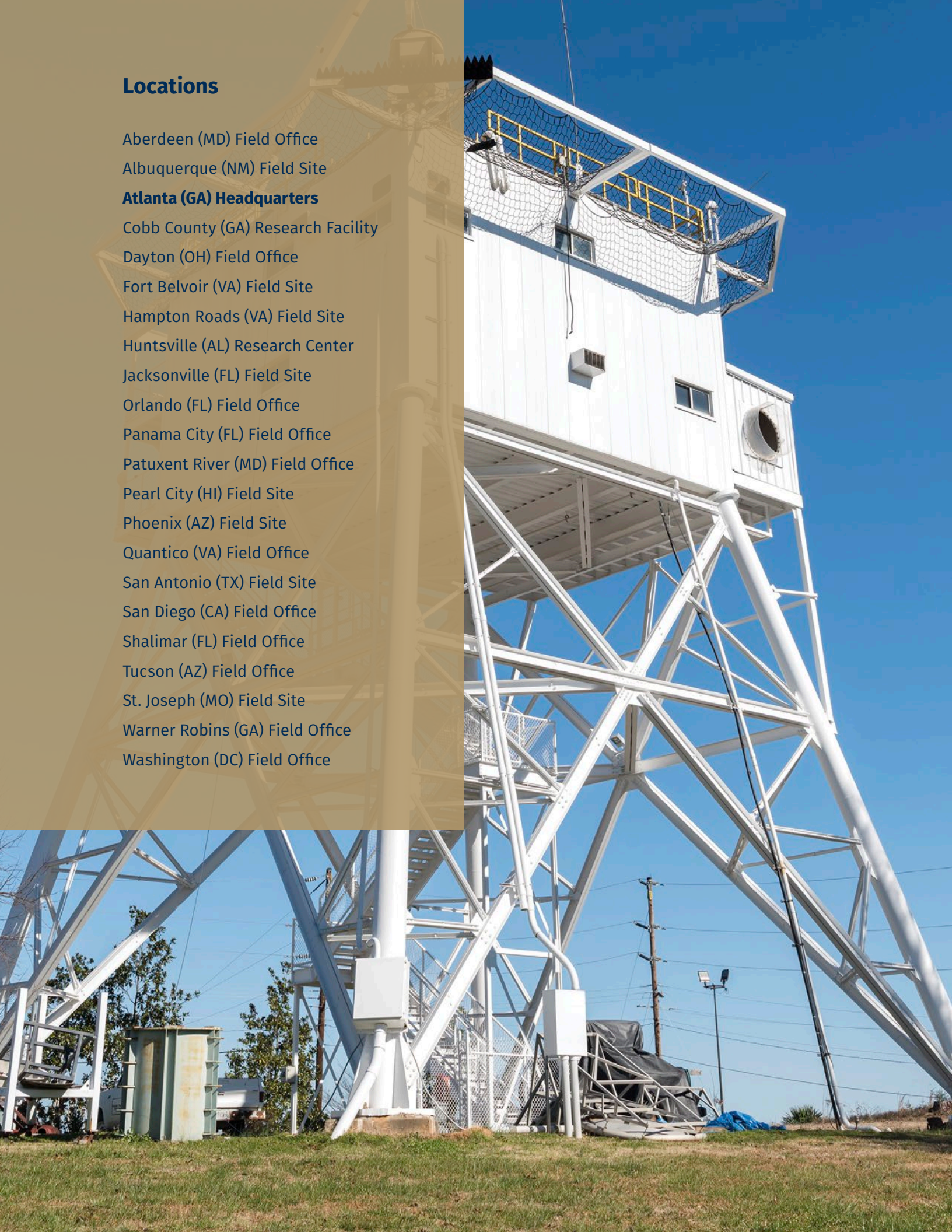
Locations

Aberdeen (MD) Field Office
Albuquerque (NM) Field Site
Atlanta (GA) Headquarters
Cobb County (GA) Research Facility
Dayton (OH) Field Office
Fort Belvoir (VA) Field Site
Hampton Roads (VA) Field Site
Huntsville (AL) Research Center
Jacksonville (FL) Field Site
Orlando (FL) Field Office
Panama City (FL) Field Office
Patuxent River (MD) Field Office
Pearl City (HI) Field Site
Phoenix (AZ) Field Site
Quantico (VA) Field Office
San Antonio (TX) Field Site
San Diego (CA) Field Office
Shalimar (FL) Field Office
Tucson (AZ) Field Office
St. Joseph (MO) Field Site
Warner Robins (GA) Field Office
Washington (DC) Field Office



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ON TWITTER twitter.com/GTRI

ON LINKEDIN tinyurl.com/GTRIresearch

Georgia Tech Research Institute