Center for Urban and Regional Air Mobility

2019 LAUNCH REPORT

Georgia Tech

CREATING THE NEXT®

At Georgia Tech, we envision a future where

air taxis seamlessly integrate with self-driving cars to better connect individuals with employment and medical centers.

autonomous technologies blur the lines between ground and air transportation.

we electrify our transportation system to allow vehicles to return energy to the grid.

robotic landing gear allows us to safely land drones and air taxis in difficult terrain and weather conditions.

robust modeling and simulation tools help us develop control algorithms that provide favorable handling qualities and control performance for new aircraft designs.

an integrated freight delivery system uses large drones to bypass traffic congestion, land on the roofs of delivery trucks, and resupply the trucks.

the batteries we use to power aircraft are reasonably priced, durable, and carbon-neutral.

our aircraft and air traffic control systems are highly automated yet seamlessly integrated with human decision-making.

we use 3D printing to quickly prototype aircraft designs.

Welcome.

Twenty years ago, Georgia Tech launched one of the first research groups and competition teams within academia focused on aerial robotics. The team's Yamaha helicopter, powered by a gasoline engine, carried an avionics box the size of a large desktop computer for its automatic flight control system. This complex research program required sizeable investment and achieved only the beginnings of what we would now recognize as autonomous flight.

Fast forward to today, and students at universities worldwide regularly fly small quadcopter "drones" around campus both for research and for fun. These small aircraft have reaped the benefits of the consumer electronics revolution. Replacing a gasoline engine is an electric propulsion system enabled by high energy density lithium-ion batteries and brushless DC motors. The ability to accurately control the RPM of the motors enables the entire concept of a quadcopter, allowing simple all-axis control of a hovering vertical flight vehicle. The avionics box is now the size of a matchbook.

An inevitable question to ask is: Can this impressive technology—which trends in consumer electronics allowed us to shrink—be scaled back up to affect larger aircraft? Could electric, autonomous aircraft be developed to carry packages or even passengers?

Despite the many challenges, it is becoming clear that the answer to this question is a resounding and exciting "yes." Over the last five years, led by quiet startup companies and exploratory work by the aerospace industry and research organizations, several prototype electric vertical takeoff and landing (eVTOL) aircraft capable of carrying passengers have been developed. What began as a few bold bets by a handful of organizations has now become the focus of widespread investment, not just by traditional aerospace companies but also by new entrants, including Silicon Valley unicorns and automotive companies who aspire to position themselves at the forefront of this new technology.

Why the investment? The answer is that eVTOLs—and similar conventional- and short- takeoff and landing aircraft—show great promise in offering an economically attractive way to save our most valuable commodity: time. By accessing the "third dimension" and flying over road traffic at high speeds, new forms of urban air mobility (UAM) may shorten commutes and other cross-city trips dramatically, resulting in more time for productive work or leisure and allowing people to live farther from where they want to go. The value proposition of "air taxis" and other UAM services is enormous, particularly as cities and their congestion continue to grow. Additionally, UAM and similar new forms of regional aviation may offer compelling benefits by connecting suburban and rural communities to urban centers, potentially enabling increased wages for rural residents and encouraging rural growth and development.

In this context, and recognizing the opportunity for society, we have formed the Georgia Tech Center for Urban and Regional Air Mobility (CURAM). Our goals are to conduct research to overcome the technical challenges of ubiquitous urban and regional flight and to educate the workforce that will bring these new modes of transportation to fruition. CURAM serves as a focal point for integrating Georgia Tech's deep expertise across the engineering disciplines and for leveraging our considerable strengths in policy, planning, and economics. Our work will focus not only on the technologies needed to enable autonomous electric aircraft but also on the technologies and strategies to integrate aviation infrastructure and aircraft operations more holistically into the fabric of cities, respecting concerns for noise, safety, privacy, and equity.

This inaugural report highlights research activities and laboratories at Georgia Tech that support CURAM's mission. The report also serves as a "time capsule," capturing our visions of how we think a future of urban and regional mobility will materialize and anticipating challenges and opportunities that we will face along the way. Twenty years from now, it will be interesting to "open" our time capsule to discover how many of our visions have come true.

We invite you to join us on our journey of exploring and enabling urban and regional air mobility.

Brian German
Director

Laurie Garrow
Associate Director

DESIGNER: Winnie Hulme
EDITORS: Sharon Dunn, Joshua Stewart
WRITER: Laurie Garrow
IMAGES COURTESY OF: Uber Elevate (cover, 4, 12, 20, 22), Airbus (7, 16, 19, 21), Yongmin Kim (10), Boeing (11), Bell Flight (14)

Contents

Defining the research agenda for aviation

John-Paul "J-P" Clarke is a College of Engineering Dean's Professor who holds appointments in the Daniel Guggenheim School of Aerospace Engineering and the H. Milton Stewart School of Industrial and Systems Engineering. Clarke is a leading expert in aircraft trajectory prediction and optimization, especially as it pertains to the development of flight procedures that reduce the environmental impact of aviation.

Clarke has served on several national committees that are defining the future research agenda for aviation. He was co-chair of the committee that developed the U.S. National Agenda for Autonomy Research related to civil aviation, and a member of the committee that reviewed the Next Generation Air Transportation System. In July 2018, Clarke provided congressional testimony before the Committee on Science, Space, and Technology of the U.S. House of Representatives. In Clarke's vision, for the future of urban air mobility to be realized, we will need to address a wide range of challenges and research opportunities related to autonomy, modeling and optimization, and policy:

- Passenger and cargo aircraft must be designed for both autonomous operations and autonomous decision-making.
- The scheduling and management of vertiport arrivals and departures must be more precise and timely than currently possible, and will also require systems that can operate autonomously.
- Vertiport locations and flight trajectories must be jointly optimized for efficiency, noise, privacy, and safety.
- Legislation may be needed with respect to certification requirements for vehicles, systems, and operators.

"My sense is that UAM will ultimately involve the movement of both people and cargo between their origins and destinations, and it will very likely also require a dynamic hub-and-spoke network."

JOHN-PAUL CLARKE

STATEMENT MADE BEFORE THE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY, U.S. HOUSE OF REPRESENTATIVES

Creating a more resilient electrical grid

Marilyn Brown is a Regents Professor and Brook Byers Professor of Sustainable Systems in the School of Public Policy. She joined Georgia Tech in 2006 after a distinguished career at the U.S. Department of Energy's Oak Ridge National Laboratory, where she led several national climate change mitigation studies and became a leader in the analysis and interpretation of energy futures. She has served as a presidential appointee to the board of directors for the Tennessee Valley Authority and in 2007 was named co-recipient of the Nobel Prize for co-authoring the Intergovernmental Panel on Climate Change Report on Mitigation of Climate Change.

One of Brown's research areas focuses on the design and impact of policies aimed at accelerating the deployment of innovations on the customer side of the electric meter. "Our continued push to decarbonize the electric grid combined with the impending electrification of transportation provide us with novel types of adaptation strategies," she explains. "I am very interested in understanding the role of the grid integrated with electric ground and electric air vehicles." Brown indicates that over the past few years, in communities where rooftop solar systems have expanded, the peak period in which non-renewable energy is needed has shifted to later in the afternoon and early evening. These peaks are also shifting geospatially as we transition to cleaner energy. For example, in New York, the peak demand was previously in Manhattan but has shifted to the boroughs of Queens and Brooklyn.

Brown is interested in exploring policies that allow us to increase our grid resiliency and better serve peak periods by allowing electric vehicles to sell their services back to the electric system. Designing such a system could also have significant benefits in times of disaster recovery, for example, providing a backup electricity source in the aftermath of hurricanes. "We have an opportunity to blend our transportation and our electricity transformations to create complementarity and a new type of adaptation strategy with renewables so that vehicles are that much cleaner and our grid is that much more resilient."

"I envision a future in which we electrify our transportation system to allow vehicles to return energy to the grid to improve the resiliency of our electricity system."

MARILYN BROWN

2007 NOBEL LAUREATE AND PROFESSOR OF PUBLIC POLICY

> "I imagine a future in which autonomous technologies blur the lines between ground and air transportation."
>
> **PANAGIOTIS TSIOTRAS**
> ASSOCIATE DIRECTOR OF THE INSTITUTE FOR ROBOTICS AND INTELLIGENT MACHINES

Generating real-time trajectories

Panagiotis "Panos" Tsiotras is the David and Andrew Lewis Chair and professor in the School of Aerospace Engineering and associate director of the Georgia Tech Institute for Robotics and Intelligent Machines. One of his primary research areas focuses on generating reliable, real-time trajectories for collision-free path control. "The first step to successfully routing an autonomous air vehicle is to take off and land reliably under both normal and unexpected conditions," Tsiotras states. "Real-time trajectory generation is critical to achieving safe landing and avoiding collisions when something unexpected happens."

As an expert who has applied autonomous controls to both ground and air vehicles, Tsiotras envisions "a future in which the lines between ground and air vehicles become blurred. Imagine a world in which we can extend the range of package delivery via drones by integrating the delivery networks for drones and ground vehicles. If a ground delivery vehicle and drone are both headed in the same direction, we could land the drone on a moving target [the ground vehicle] and let the ground vehicle transport the drone until their paths diverge."

Tsiotras also envisions that workforce development will be critical to the success of urban and regional air mobility. "As autonomous ground and air vehicles become more complex, the traditional role of the car mechanic will change, and the current decentralized system of aircraft maintenance used today by commercial airlines may become obsolete. If highly specialized training is needed to maintain autonomous systems, this function could transition to the aircraft manufacturers."

> "I envision an integrated freight delivery system that uses large drones to bypass traffic congestion, land on the roofs of delivery trucks, and resupply the trucks."
>
> **MARTIN SAVELSBERGH**
> PROFESSOR OF INDUSTRIAL AND SYSTEMS ENGINEERING

Envisioning rapid deliveries

Martin Savelsbergh is the James C. Edenfield Chair and professor in the School of Industrial and Systems Engineering. Savelsbergh is an optimization and logistics specialist known for developing innovations in last-mile delivery, advances in dynamic ridesharing, methods for multi-objective optimization, and dynamic management of time-expanded networks.

Savelsbergh and colleague John-Paul Clarke have been investigating how drones, in combination with ground-delivery vehicles, can be used for rapid home deliveries. "As the popularity of online shopping has grown, so too has the desire of consumers to have same-day deliveries. As traffic congestion in cities continues to worsen, retailers and delivery companies are seeking new solutions to provide cost-effective, flexible, and fast direct-to-consumer deliveries," Savelsbergh points out.

Savelsbergh and Clarke envision a system in which a fleet of drones is used to resupply delivery trucks. They note that this "solves the issue of how to handle delivery addresses without an obvious place for a drone to drop off a package" and that this "enhances safety as the drone, because it will be larger, will be more stable and less vulnerable to adverse weather conditions." Synchronization is the most challenging feature of their envisioned home-delivery system: "Because the delivery truck and the drone can meet at pretty much any location for resupply to take place, determining the latest possible dispatch time of a package at the fulfillment center so as to reach its destination at (or before) the committed delivery time is far from trivial."

Rapid prototyping to test aircraft designs

Claudio V. Di Leo is an assistant professor of aerospace engineering. Di Leo's research group, the Multiphysics Mechanics of Materials Lab, studies the broad topic of modeling the coupling of chemical phenomena and mechanical deformation. Di Leo has a particular interest in energy storage devices and has studied the role of mechanics on electrochemical performance of nano-architected lithium-ion battery electrodes. He also directs the Aero Maker Space, an educational lab that enables students to do rapid prototyping and testing of novel ideas.

> "I envision a future where we use 3D printing to quickly prototype aircraft designs and use advanced smart materials to tell us when maintenance is needed."
>
> **CLAUDIO DI LEO**
> ASSISTANT PROFESSOR OF AEROSPACE ENGINEERING

Di Leo has used 3D printing as part of a Defense Advanced Research Projects Agency (DARPA)-sponsored project in collaboration with Boeing that involves the design, manufacturing, and flight-testing of a robotic landing gear (RLG) concept for rotorcraft. "We developed a novel four-bar, cable-driven leg mechanism, as well as novel ground contact sensors based on rubber-encapsulated pressure sensors, for a 400-pound unmanned aerial vehicle," he says. The RLG system was successfully flight-tested in March 2018.

Through understanding the coupling between mechanics and chemistry, Di Leo envisions the design and development of novel smart materials and structures for application in urban and regional air mobility. For example, he envisions the power source of an unmanned aerial vehicle (UAV) distributed throughout the airframe inside structural components. These structural components would also be used for sensing mechanical loads through the airframe and providing health monitoring of the energy storage system.

Testing and strengthening structural systems

Julian J. Rimoli is an associate professor of aerospace engineering. His research interests lie within the broad field of computational mechanics of materials and structures, with particular focus on aerospace applications. Rimoli has a special interest in problems involving multiple length and time scales, and in the development of theories and computational techniques for seamlessly bridging them.

> "I envision a future where we use augmented and virtual reality tools combined with deep learning modeling frameworks to test aircraft concepts in real time."
>
> **JULIAN RIMOLI**
> ASSOCIATE PROFESSOR OF AEROSPACE ENGINEERING

Rimoli has developed a technology aimed at strengthening structural systems that are primarily composed of bars and strings, and which look like a child's jungle gym. "These tensegrity lattices allow for the building of resilient structures that can be severely deformed without losing their load-bearing ability," Rimoli offers. "There are several aviation-related applications for these structures, particularly from a crashworthiness perspective for commercial aircraft or drone package deliveries."

Rimoli also is passionate about helping students gain a conceptual understanding of the fundamental aspects of structural mechanics. He has developed an educational app called "Truss Me!" This app allows a user to build a truss and see how the design performs. If there are flaws in the design, the structure realistically fails. Rimoli has extended this concept to his own research, equipping his test structures with sensors that record acceleration and material properties during impact. Then he uses augmented reality to "walk" through the structure and see where the damage occurred.

Rimoli sees applications of augmented and virtual reality—coupled to physics-based models and deep learning—as the basis for exploring and evaluating new aircraft designs for urban air mobility.

Developing drone connectivity

Jonathan "Jon" Rogers is the Lockheed Martin Associate Professor of Avionics Integration in the School of Aerospace Engineering and director of the Aerial Robotics and Experimental Autonomy Lab (AREAL) where his group conducts research in applied dynamics, controls, robotics, and autonomy. One of Rogers' current research projects is focused on using multiple drones operating collaboratively to transport payloads.

"The fundamental idea is that when transporting heavy packages, instead of using one large drone, we can use multiple smaller drones that simultaneously connect to the single package, lift the package, and fly the package together," he explains.

Another area of Rogers' research is to develop automated autorotation procedures for helicopters. "Pilots use autorotation maneuvers to safely land helicopters in the event of an engine failure, but these maneuvers may become difficult for pilots at night or in degraded visual conditions when outside visual references are obscured," Rogers advises. "The problem of landing aircraft safely under emergency conditions becomes even more complex when we start thinking about aircraft designs for urban air mobility, which may lack the ability to autorotate."

Rogers' vision of the future of UAM is motivated by the fact that the dominant aircraft designs have not yet been decided. "There are so many novel designs for urban and regional air mobility aircraft; we as a research community could benefit from reconfigurable, high-fidelity modeling and simulation tools to better understand aircraft performance and handling qualities under a wide range of conditions before we build out large-scale prototypes."

"In my vision of the future, robust modeling and simulation tools help guide the development of control algorithms that provide favorable handling qualities and control performance for new aircraft designs."

JON ROGERS

DIRECTOR OF THE AERIAL ROBOTICS AND EXPERIMENTAL AUTONOMY LAB

"I envision a future in which robotic landing gear allows us to safely land drones and air taxis in difficult terrain and weather conditions."

MARK COSTELLO

SCHOOL CHAIR OF AEROSPACE ENGINEERING AND DIRECTOR OF THE CENTER FOR ADVANCED MACHINE MOBILITY

Investigating robotic landing gear

Mark Costello is the William R.T. Oakes School Chair of the School of Aerospace Engineering and director of the Center for Advanced Machine Mobility. Costello most recently completed an assignment at the Defense Advanced Research Projects Agency where he served as a program manager in the Tactical Technology Office. Costello works in the areas of dynamics, control, and design, and his research focuses on the development of innovative flight mechanics and controls technologies for a variety of flight vehicles, including rotorcraft, projectiles, parafoils, and unmanned aerial vehicles.

One aspect of Costello's research focuses on actively controlling the aircraft and landing-surface interface. For example, his research team is investigating the use of robotic landing gear using both dynamic simulation and experimental laboratory testing. "Robotic landing gear could expand the available landing areas for drones to deliver packages, including safely landing on the roofs of delivery trucks," Costello offers. "Robotic landing gear could also be used to help improve the reliability of safe landing of air taxis under a variety of inclement weather scenarios."

> "I envision a future where we achieve our sustainability goals by simultaneously optimizing the transportation networks and infrastructure requirements for autonomous ground vehicles and urban air mobility."
>
> **SUBHRO GUHATHAKURTA**
>
> DIRECTOR OF THE CENTER FOR SPATIAL PLANNING ANALYTICS AND VISUALIZATION

Assessing sustainability outcomes

Subhrajit "Subhro" Guhathakurta is chair of the School of City and Regional Planning and director of the Center for Spatial Planning Analytics and Visualization. Guhathakurta's research assesses how decisions made about urban growth relate to sustainability. He develops metrics and benchmarks for assessing sustainability outcomes and uses creative visualization techniques to make his analysis relevant to non-experts.

Guhathakurta has conducted extensive research assessing the potential impact of autonomous ground vehicles on urban form and land-use patterns. "Different business models for autonomous ground vehicles have been proposed and include shared AVs (SAVs) and private AVs (PAVs)," he explains. "A future of PAVs will likely lead to increases in the total vehicle miles traveled due to unoccupied vehicle movement. With the popularization of SAVs, we expect that the city centers would benefit from more accessibility and better amenities, partly through space made available from repurposed parking spots. Demand for parking infrastructure could decrease significantly." However, he also cautions that "this future is possible only with deliberate and smart planning of our cities."

In the context of future urban air mobility, Guhathakurta sees many connections between autonomous ground vehicles and urban air mobility operations. "Ground AVs will likely lead to a decrease in demand for parking structures," he says. "We could identify parking facilities that will have a low utilization and potentially repurpose those structures to serve UAM operations."

> "I envision a future in which air taxis seamlessly integrate with self-driving cars and better connect individuals with employment and medical centers."
>
> **LAURIE GARROW**
>
> ASSOCIATE DIRECTOR OF THE CENTER FOR URBAN AND REGIONAL AIR MOBILITY

Predicting demand for new services

Laurie Garrow is the associate director of the Center for Urban and Regional Air Mobility and professor in the School of Civil and Environmental Engineering. Her research focuses on modeling airline customer behavior and understanding how customer preferences translate to demand for products and services.

Garrow's research group has been conducting focus groups and market surveys to predict demand for new air taxi services and to better understand how air taxis could influence the urban landscape. "Air taxis hold the potential to transform our cities," she states. "Air taxis can benefit rural and urban areas by better connecting people and jobs, particularly in metropolitan areas that have geographic features such as mountains or waterways that result in circuitous roadway or transit networks. However, air taxis could further encourage urban sprawl by drastically reducing commute times between suburban communities and urban centers."

Garrow's research group is also exploring potential competition between air taxis and self-driving cars. "The future is unknown, but if self-driving cars provide a smooth ride that allows individuals to productively use their laptops, the attraction of using an air taxi to avoid traffic congestion could decrease."

Reinventing aviation

Brian German is the director of the Center for Urban and Regional Air Mobility and the National Institute of Aerospace Langley Associate Professor in the Daniel Guggenheim School of Aerospace Engineering. German is an expert in the design, optimization, and performance analysis of aircraft with electric propulsion.

Much of German's work has focused on modeling battery performance for eVTOL and electric regional aircraft and studying the impact of recharge time and battery replacement costs on UAM operations and economics. He has also led several NASA-sponsored research projects related to UAM operations, focusing on topics such as vertiport placement and network simulation. German regularly leads student teams to develop, prototype, and conduct flight tests of novel electric aircraft designs.

"The idea of urban air mobility is exciting because it represents the opportunity to reinvent both the aircraft and the entire aviation enterprise," German shares. "The Vertical Flight Society is now tracking over 150 widely differing eVTOL aircraft designs that are currently in development, and we do not yet know which type will be most successful for urban aviation."

> "The idea of urban air mobility is exciting because it represents the opportunity to reinvent both the aircraft and the entire aviation enterprise."
>
> **BRIAN GERMAN**
>
> DIRECTOR OF THE CENTER FOR URBAN AND REGIONAL AIR MOBILITY

Teaching machines and humans

Karen Feigh is an associate professor of aerospace engineering. Feigh is active in the design of cognitive work support systems for individuals and teams in dynamic sociotechnical settings, including airline operations, air transportation systems, and unmanned aerial vehicle ground control stations.

Feigh recently developed an interface to assist astronauts with safely and efficiently executing extravehicular activities. She has also focused on better understanding how people can naturally and intuitively teach machines to perform tasks. "Imagine that you owned a robot to help perform household chores, but the robot didn't know how you liked your clothes folded or where to put them, what dishes needed to be handwashed instead of going into the dishwasher, et cetera," she illustrates. "In these types of situations, the integration of robotics into our work processes requires that machine learning agents are readily able to learn from human teachers and to do so in very straightforward and nonfrustrating ways."

"In the context of urban and regional air mobility, there have been ongoing discussions as to whether these aircraft will be autonomous and/or if we can decrease the amount of pilot training required. That opens up a wide range of research questions that we need to explore. For example, will we have autonomous algorithms that can detect if a pilot is doing something that appears to be unsafe and, if so, when should those algorithms trigger action? Will we have emergency pilots who are on the ground somewhere and, if so, how can we design systems for them to handle a workload that will likely involve highly congested air space?"

> "I envision a future of urban and regional air mobility in which we have designed our aircraft and air traffic control systems to be highly automated and yet seamlessly integrated with human decision-making."
>
> **KAREN FEIGH**
>
> ASSOCIATE PROFESSOR OF AEROSPACE ENGINEERING

Making more durable batteries

Thomas "Tom" Fuller is a professor in the School of Chemical and Biomolecular Engineering. His primary area of research focuses on the design, development, and testing of battery, fuel-cell, and hybrid power systems. "We know how to make really great fuel cells and batteries that minimize environmental impacts, but the costs of making these batteries are prohibitive for many applications," he discloses. "My research focuses on helping understand how to make electrochemical systems more durable and longer lasting, which ultimately lowers their life-cycle costs."

Fuller, along with colleagues David Taylor and Michael Leamy, are faculty advisors to EcoCAR, an international student competition organized by the U.S. Department of Energy, General Motors, and MathWorks. The program is managed by Argonne National Laboratory, and the most recent four-year competition, the EcoCAR Mobility Challenge, started in 2018. Twelve university teams are tasked with applying advanced propulsion systems as well as connected and automated vehicle technologies to improve the energy efficiency, safety, and consumer appeal of the 2019 Chevrolet Blazer. This current round of the competition is specifically focused on the car-sharing market. "These competitions provide a rich educational opportunity for engineering students across departments to collaborate in the design of a vehicle and get their hands dirty trying out different solutions to balance environmental and performance objectives."

"I envision a future in which the batteries we use are reasonably priced, durable, and carbon-neutral."

TOM FULLER

PROFESSOR OF CHEMICAL AND BIOMOLECULAR ENGINEERING

Fostering dialog on UAM

Simon Briceno is a senior research engineer who leads the Transformative Aviation Concepts Division of the Aerospace Systems Design Laboratory. He and his team have worked with NASA Langley to better understand the value proposition of electrified commuter airplanes for regional markets and have analyzed battery recharging in electric aircraft operations via several case studies. "In addition to using cleaner energy, air vehicles with electrified propulsion can provide significant cost savings over comparable fossil–fuel powered aircraft," Briceno states.

Most recently, Briceno was part of a NASA project that conducted a market assessment of the viability of UAM, identified potential barriers, and proposed solutions. "Our analysis showed that both last-mile package delivery and an air metro service could be financially viable as early as 2030 if we can address physical, operational, and integration challenges of a highly interdependent system of systems," he says.

Briceno also serves as Georgia Tech's deputy site director for the Partnership to Enhance General Aviation Safety, Accessibility, and Sustainability (PEGASAS), a Federal Aviation Administration (FAA) Center of Excellence for General Aviation. He is lead author on an FAA report published in 2018 that documents strategic general aviation (GA) research topics that will be important for GA stakeholders to address in order to fully participate in the emerging urban and regional air mobility models.

Looking ahead, Briceno is particularly interested in identifying community-level barriers that engineers will need to address to make urban and regional air mobility a reality. "We can design sophisticated air vehicles that overcome technical hurdles, but if the public is afraid to fly in them, or if local communities block building permits for vertiports and other required infrastructure, we will literally not get off the ground," Briceno emphasizes.

"I envision a future in which industry, community, and public stakeholders engage in open dialog to overcome potential barriers and jointly create a future where urban and regional air mobility enhances our quality of life."

SIMON BRICENO

TRANSFORMATIVE AVIATION CONCEPTS LEAD IN THE AEROSPACE SYSTEMS DESIGN LAB

Flying into the future

It all began when **Alistair Sequeira**, an undergraduate student in aerospace engineering at Georgia Tech, saw an advertisement for Boeing's GoFly competition, which seeks to "foster the development of safe, quiet, ultra-compact, near-VTOL personal flying devices capable of flying 20 miles while carrying a single person." Sequeira put together a design team in January 2018 and called their future device HummingBuzz — a nod to Georgia Tech's yellow jacket mascot. A broad group of Georgia Tech undergrad and grad students worked together for two full semesters to design HummingBuzz. The effort was headed up by aerospace engineering professor Daniel Schrage.

The students submitted a technical paper as part of Phase I of the competition. HummingBuzz was one of 10 winners selected from more than 750 submissions. Although several members of the original team have graduated, Sequeira continues to help spearhead the effort. The team submitted their design tests for Phase II of the GoFly competition in February 2019.

"Regardless of whether we win the Phase II competition, we are going to compete in the final Phase III competition," Sequeira stated. "Looking into the future, I am very excited about applying what I have learned to design drones and aircraft that can be used in agriculture, construction, and search-and-rescue operations."

> "I envision a future in which, instead of taking a bike, we jump on a personal flying device like HummingBuzz and fly to where we need to go."
>
> **ALISTAIR SEQUEIRA**
> AE UNDERGRADUATE AND HUMMINGBUZZ TEAM MEMBER

Evaluating vertical lift vehicle designs

Marilyn Smith is a professor of aerospace engineering and director of the Vertical Lift Research Center of Excellence (VLRCOE) at Georgia Tech. She became center director in November 2018 when Daniel Schrage, who led the center for more than 30 years, announced his retirement. The VLRCOE at Georgia Tech conducts basic research focused on scientific barriers in technologies that support current and future vertical lift capabilities. Funded by a consortium of sponsors, including the U.S. Army, U.S. Navy, and NASA, the VLRCOE at Georgia Tech is part of a national network of vertical lift research programs housed at academic institutions. Over the course of its history, Georgia Tech's VLRCOE has promoted research that has resulted in software algorithms and simulation models that are now in regular use by the U.S. government and the rotorcraft industy.

Smith is an expert in vehicle aeromechanics and fluid–structure interactions and the influence of these interactions on vertical takeoff and landing (VTOL) flight vehicles. "There is much we have to learn about how various eVTOL aircraft will perform and which designs will best serve urban and rural mobility missions for passengers and cargo," Smith acknowledges. "Software and simulation models that are used to design rotorcraft can be enhanced to evaluate rotary wing–based flight vehicle designs for urban and regional air missions and directly tie performance criteria to the passenger experience."

> "I envision a future in which we develop algorithms and simulation tools to design VTOL flight vehicles for urban and regional air mobility applications that increase safety and improve the passenger experience in terms of noise, vibration, and ride quality."
>
> **MARILYN SMITH**
> DIRECTOR OF THE VERTICAL LIFT RESEARCH CENTER OF EXCELLENCE

"UAM research must be a highly collaborative effort. We will need to think about how all of the pieces fit together, including the vehicles, autonomy, communication networks, operations, and FAA airworthiness concerns."

COURT BIVENS

CHIEF OF ENGINEERING, GTRI

Taking a systems engineering approach

Courtland "Court" Bivens is the chief of engineering in the Aerospace, Transportation, and Advanced System (ATAS) Laboratory at the Georgia Tech Research Institute (GTRI). At GTRI, Bivens is responsible for cultivating relationships between technology-related businesses, academia, and Georgia Tech faculty researchers. GTRI has extensive capabilities related to UAV technologies, design, and analysis, and has experience in conducting the test and evaluation of aircraft performance.

"I view urban air mobility as a natural extension of the growth of an advanced transportation-focused civilization in Atlanta," Bivens says. "Atlanta has a rich history of being a hub for transportation … and today Hartsfield–Jackson Atlanta International Airport has the highest passenger and logistics traffic in the world and is a major international hub."

Bivens is an expert in systems engineering. "Systems engineering is especially relevant to the planning and development of a technologically incomparable regional urban air mobility capability," he explains. "We will need to think about not only the vehicles, autonomy, communication networks, operations, and FAA airworthiness concerns, but also all of the additional supporting infrastructure and personnel that a successful UAM capability will necessitate. A systems engineering approach will allow us to visualize the future and optimize the interactions between the different systems and better understand how one decision can affect others. The more fidelity you add to your systems engineering model, the better answers you can find for what outcome you want to foster."

"The Blast, Shock, and Impact Lab allows us to model the effects of repeated air taxi operations on skyscrapers and parking facilities."

LAUREN STEWART

DIRECTOR OF THE BLAST, SHOCK, AND IMPACT LABORATORY

Testing impacts

Lauren Stewart is associate professor of civil engineering and director of the Blast, Shock, and Impact Laboratory, one of just two facilities in the U.S. capable of simulating shock events on a variety of structures and materials. An ultrahigh-speed hydraulic actuator induces forces on the test structures for durations on the order of milliseconds to produce an impulsive blast-like load. This allows researchers to replicate shock events on structures in a controlled experimental setting. A high-speed data acquisition system collects data on how the structures respond.

Stewart's research group has used the high-speed actuators to simulate vehicle impacts on guardrails and other highway safety structures. With respect to aviation applications, her lab could be used to test the performance of landing gear under repetitive landings or hard landings, as well as the performance of different fuselage designs and materials in response to bird strikes, other types of mid-air collisions, or simulated explosions.

Stewart envisions several problems specific to urban air mobility that the Blast, Shock, and Impact Lab can help address. "I never envisioned a city in which air taxis would repeatedly take off and land on buildings and parking structures. As structural engineers, we need to better understand how buildings perform under repeated heavy loadings and ensure that these structures are capable of withstanding the effects of repeated hard landings and potential collisions with aircraft."

Transforming cities through innovation

Debra Lam is the managing director of Smart Cities and Inclusive Innovation, a role created in 2018 to forge a path of innovation and next-generation planning and data analytics that will help transform cities throughout the world into smarter, more efficient places to live and work. Prior to joining Georgia Tech, Lam served as chief innovation and performance officer for the City of Pittsburgh, where she led developments in innovation, open data, and resilience.

Lam is responsible for actively engaging with government and industry partners. One of the key initiatives is the Georgia Smart Communities Challenge (Georgia Smart), which provides funding and technical assistance for local governments within the state of Georgia.

Georgia Smart supports cities, counties, and consolidated city–county governments to explore the use, deployment, or integration of smart community technologies into their jurisdictions and operations. These technologies include intelligent infrastructures, information and communication technologies, Internet of Things (IoT) devices, and other computational or digital technologies, such as data centers and portals, web and smartphone applications, and automated digital services.

Georgia Smart is organized by Georgia Tech in partnership with the Global City Teams Challenge and 10 business and government organizations in Georgia.

» "I am excited to see how we can use our Georgia Smart competition to explore how urban and regional air mobility can help Georgia strengthen its economy, better connect people and jobs, and improve mobility for people and freight."

DEBRA LAM

MANAGING DIRECTOR OF SMART CITIES AND INCLUSIVE INNOVATION

Georgia aerospace: Soaring to new heights

#1
aerospace sector's rank amongst Georgia exports in 2019

$57.5B
aerospace industry's economic impact in 2017

$9.1B
value of exports in 2019

840
aerospace companies

15
years aerospace has been #1 export

108,000
aerospace employees

5th
Georgia's rank amongst U.S. states for aerospace exports

6%
aerospace contribution to state gross domestic product (GDP)

107.4M
Hartsfield–Jackson Atlanta International Airport passengers in 2018

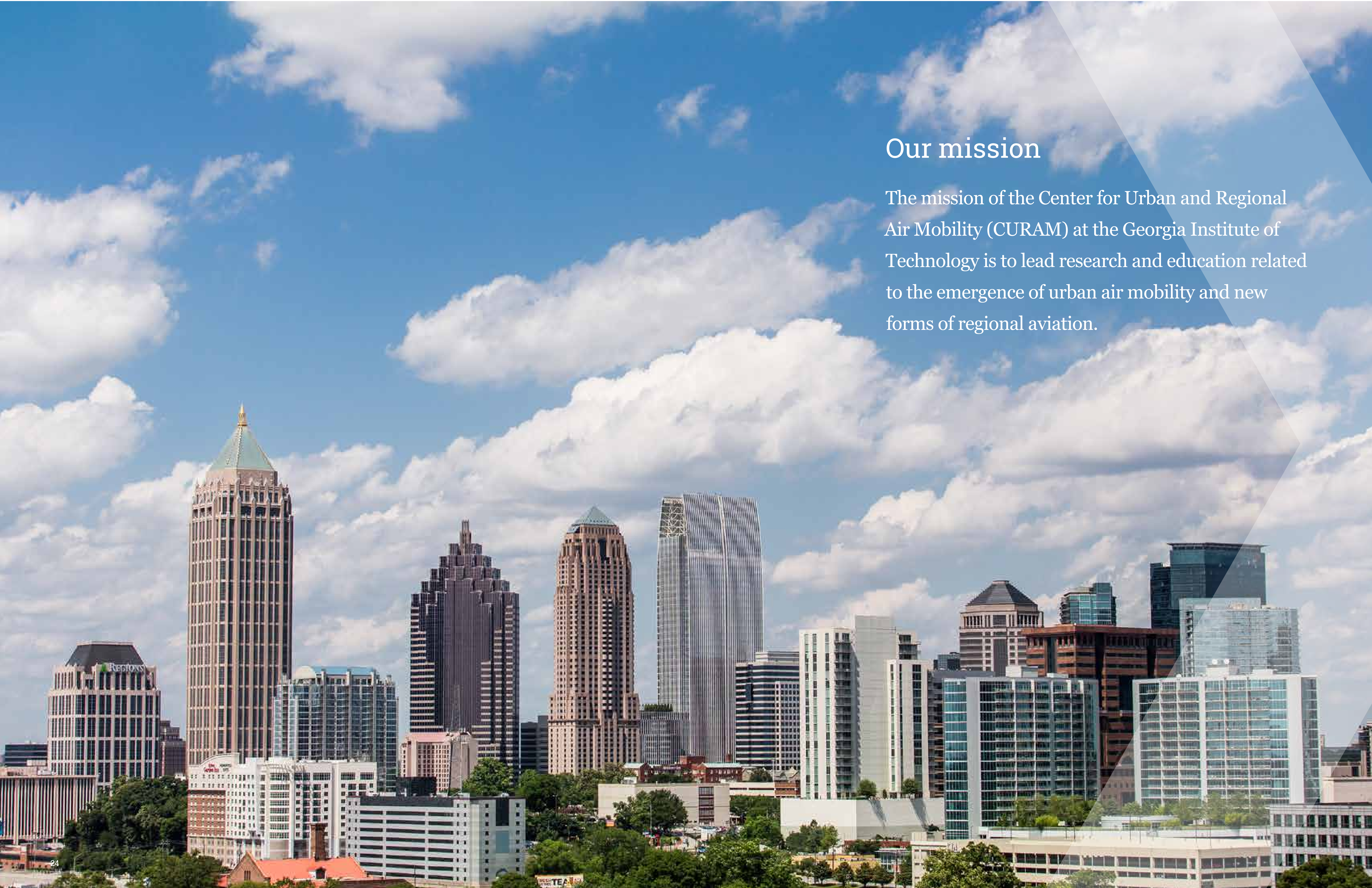
$77K
average aerospace wage

"... Emerging technologies are enabling new types of aircraft for urban and regional transportation; Georgia's aerospace industry and academic researchers seek to advance the concepts and technologies necessary to safely and efficiently integrate unmanned aircraft into the National Airspace System ..."

HOUSE RESOLUTION 382

RECOGNIZING THE FUTURE OF URBAN AIR MOBILITY IN GEORGIA

Georgia Governor **Brian Kemp** speaks at the 9th Annual Georgia Aerospace Day in February 2019.



Our mission

The mission of the Center for Urban and Regional Air Mobility (CURAM) at the Georgia Institute of Technology is to lead research and education related to the emergence of urban air mobility and new forms of regional aviation.

CREATING THE NEXT®

Georgia Tech | Center for Urban and Regional Air Mobility

airmobility.gatech.edu