GDOT

Georgia Department of Transportation

ADVANCED AIR MOBILITY STUDY

TECHNICAL REPORT

APRIL 2024

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1. Introduction

1.1 Overview of Advanced Air Mobility (AAM)

Advanced Air Mobility (AAM) is an emerging transportation system designed to move cargo and passengers at low altitudes within urban, suburban, and rural areas. This system builds upon the concept of Urban Air Mobility (UAM) by expanding its range (e.g., inter-city and regional travel) and use cases (e.g., air ambulance, firefighting, law enforcement).

The key element behind each of these concepts stems from the advent of Distributed Electrical Propulsion (DEP) in aviation. DEP technology is based on the premise that closely integrating the propulsion system with the airframe and distributing multiple motors across the wing will increase efficiency, lower operating costs, and increase safety (Clarke, 2021). Innovations in DEP systems, electronic controllers, and battery systems evolve continuously, advancing the capability of aviation.

Electrical vertical takeoff and landing (eVTOL) capability is the predominant configuration for aircraft utilizing AAM technology, and as such AAM is becoming an all-encompassing acronym for aircraft and related services that use DEP, including eVTOL. The Vertical Flight Society Aircraft Directory is tracking hundreds of concepts for electric and hybrid-electric VTOL aircraft, though many of these are in early conceptual stages (Vertical Flight Society, 2023). In general, these aircraft hold somewhere between four to eight passengers, with early eVTOL flight ranges typically 60-150 miles at cruise speeds around 100-200 miles per hour.

A number of the leading original equipment manufacturers (OEM) are targeting 2025-2030 for entry into service (AAM Reality Index, 2023). The early entrants will be piloted, while later entrants hope to start out autonomously.

AAM is often described in phases—a crawl, walk, run timetable toward full-scale deployment. The first aircraft certified will have a pilot on board. These aircraft are expected to be all-electric and fly only in visual meteorological (good weather) conditions. Traffic will be managed by traditional air traffic controllers and will operate at a low frequency and volume. Over time, autonomous aircraft are expected to be introduced, power options will expand to hybrid and hydrogen systems, and flights will be allowed in instrument meteorological conditions. As the frequency and volume of operations increase, new air traffic management tools and capabilities may be necessary.

Early operations will rely on existing aviation infrastructure, like airports and heliports. As AAM progresses, however, new infrastructure will be required. AAM landing areas, known as vertiports, will be developed in greenfield sites and will support a variety of uses and users, including air taxi, air cargo, and public services. These landing sites will also need supporting infrastructure that includes (but is not limited to): electric aircraft charging stations, fire safety, high-speed data, and micro-climate weather monitoring. The benefits and impacts of these vertiports and their operations will involve coordination and planning between the federal government, state governments, local governments, and service providers, among others.

Broadly, AAM also includes Uncrewed Aerial Systems (UAS), a term that encompasses uncrewed aerial vehicles (UAVs, sometimes referred to as drones) and the supporting software and systems that enable those vehicles. UAS operations include, among many others, package delivery, aerial photography, infrastructure inspections, surveying, and agriculture. These vehicles can be operated privately or commercially, with most commercial operations falling under the FAA's Federal Aviation Regulation (FAR) Part 107 Certificated Remote Pilot license. Because small/lightweight UAVs do not require dedicated landing facilities, the role of the state or local governments is minimal since this airspace is under the oversight of the FAA. For this reason, the Georgia AAM Study is primarily focused on eVTOLs for passenger and cargo operations. This study explores a vast array of information from manufacturing to deployment, including a special focus given to local governments in the **GDOT AAM Study - Community Guidebook** document.

Given the rapid emergence of the AAM industry and federal guidance, GDOT embarked on this study to ensure the safety of the public and property, understand the basic needs of an AAM operator, assess where those operations would likely first appear, identify the gaps in infrastructure, strategically plan for new entrants, and assist with public acceptance of a new mode of transportation.

The study focused on four main tasks, as presented below:

1. **An assessment of AAM activities and its potential in Georgia.**

   The primary focus of this task was to create an informed community within the Department on AAM and detail current AAM infrastructure deployment activities. This task provided an understanding of the current state of AAM and the industry's potential impact in Georgia, including research of other states' activities on AAM, AAM Use Cases for Georgia, best practices for landing area regulation, outreach tools for AAM, and a review of the potential economic impact for AAM.

2. **An inventory of the State's potential AAM aircraft landing areas and evaluation of airport charging needs and capabilities.**

   Many concepts of operation (CONOPS) suggest that initial AAM operations will utilize existing infrastructure such as heliports and smaller airports. This task compiled an inventory of existing heliports in the state and identified one that could safely serve AAM operations based on potential airspace conflicts, surrounding infrastructure, and other factors. This task created ten airport compatibility reports to determine the infrastructure required to service AAM aircraft, such as electric charging stations and related utilities. The task also included a funding level projection to determine the estimated cost of installing electric charging stations at airports across Georgia. In addition to installation costs, the task also researched any revenue capture methods available for electric charging as well as a range of fees being charged to users based on established metrics (e.g., wattage [Kwh] used, base use fee, etc.).

3. **A community guidebook to help local governments as they are approached by AAM providers.**

   This task developed a community guidebook for local municipalities to work with developers, community members, operators, and other stakeholders in AAM who want to build, certify, or operate AAM infrastructure. The toolkit included a primer on AAM, roles and responsibilities, best practices for local governments, and a resource toolkit. Elements of the guidebook and the toolkit have been posted to the GDOT AAM website.

4. **A statewide AAM action plan.**

   This task developed an action plan of the recommended stages of AAM. This plan is a roadmap from the system's present condition to the initial operation startup, and it incorporates the feedback of the AAM Working Group. The document establishes key legislative, administrative, and strategic initiatives for GDOT and partners to invite industry to the state. The strategic initiatives include key tasks for continued coordination with stakeholders, support to local governments, workforce development tools, and economic development efforts that align with GDOT's goal to position Georgia as a leader in AAM.

The Georgia AAM Study was conducted through a panel with the engagement of key stakeholders, who formed the working group. Members of the working group included state and local government officials as well as representatives from the industry, airports, and academia. The group provided input and feedback on the AAM Study deliverables to ensure all aspects of this emerging innovation are considered.

2. Literature Review of State AAM Initiatives

This literature review and research were conducted to investigate and assess how other states across the nation are addressing, preparing for, and evaluating the potential benefits of integrating AAM into statewide transportation systems. The planning efforts and studies of other states will serve as a guide to provide GDOT with insights into potential opportunities and challenges that are presently being evaluated.

Currently, at least 20 states have or are undertaking AAM planning efforts at various levels: Arkansas, Arizona, California, Florida, Illinois, Kansas, Michigan, Minnesota, Nevada, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, Texas, Utah, Virginia, and Washington.

Key takeaways from other states' research efforts will be categorized into four primary areas of focus: **funding, ecosystem development, infrastructure, and policy**. States have identified the need to provide dedicated funding to support AAM program development and incentivize the AAM industry to develop in their state. Most states considered it essential to establish a statewide point of contact to coordinate and advocate for AAM. This point of contact is responsible for developing policies and legislation to foster development and provide a regulatory framework for safely managing AAM.

Several states considered it vital to advance STEM (Science, Technology, Engineering, and Math) education to prepare a ready workforce for AAM industry development support. Additionally, they found it would be important to establish robust AAM community engagement and public information programs. Lastly, all states analyzed infrastructure requirements and began to develop best practices. Details on the efforts of select states are outlined below.

2.1 State AAM Initiatives

1. Arkansas

Two AAM studies were recently conducted in Arkansas. In September 2021, the Walton Family Foundation published a white paper entitled *Advanced Air Mobility Comes to Arkansas* (Walton Family Foundation, 2021). The white paper detailed use cases for AAM to include passenger transport, access to healthcare, and cargo. It estimated that between now and 2045, economic activity generated by Advanced Air Mobility will bring nearly 4,000 new full-time equivalent (FTE) jobs to the State; create $3.6 billion in new economic activity and related stimulus; add 10+ percent to the growth of Arkansas' existing aerospace sector; produce $629 million in Local, State, and Federal tax revenues; and deliver substantial catalytic benefits in healthcare and STEM education. Combined, these activities will help shrink the rural-urban divide and lift the State's economy.

The white paper concluded with four recommendations:

1. Assemble a business consortium utilizing a Public Private Partnership (PPP) construct to bring government, corporations, and the public together to advance AAM funding and implementation.
2. Energize the Arkansas Aerospace Supply Chain to lead AAM advocacy for business development.
3. Initiate a legislative education and advocacy program to communicate the potential benefits of AAM as they relate to job creation and expansion of commerce in Arkansas.
4. Research catalytic benefits of AAM-supported healthcare outcomes for Arkansans.

In 2022, Arkansas Governor Asa Hutchinson formed the Arkansas Council on Future Mobility. The council was composed of 26 advisory and 18 appointed members who included private investors, government and public utility administrators, and academic experts as well as corporate leaders from companies such as retail giant Walmart, trucking company J.B. Hunt, the University of Arkansas, Tulsa Innovation Labs, Tyson Foods, Union Pacific, and Southern Arkansas University, among many others.

The council was tasked to review current legislation, design programs to expeditiously adopt emerging mobility technologies, secure federal funding, and establish education and workforce initiatives to create jobs in the state. In addition to AAM, the study also considered other mobility technologies, including space, drones, micromobility, and autonomous vehicles. The council's *Arkansas Future Mobility Report* (Arkansas Future Mobility Council, 2022) was published in December 2022 and contained 35 recommendations for state-level implementation. The 10 recommendations regarding aviation-related technologies included:

1. Establish partnerships with Tennessee and Texas to form a regional mobility Super Hub.
2. Create the Arkansas Innovation Fund to invest in emerging companies.
3. Expand STEM education and workforce development in the state.
4. Establish an Arkansas Space Authority.
5. Execute a feasibility study on the development of an Arkansas Spaceport.
6. Continue to support the acceleration of growth and availability for drone delivery services across the state and beyond, including partnerships with drone companies to launch essential healthcare services in rural communities.
7. Work with stakeholders (both inside and outside the state) to express and build support for FAA implementation of Beyond Visual Line of Sight (BVLOS) operations.
8. Proactively support those seeking to develop ground infrastructure for AAM, especially by facilitating expedited permitting required for electrical infrastructure work.
9. While AAM infrastructure is being developed, take a lead role in surveying concerns and educating citizens about AAM's benefits to ensure public acceptance.
10. Implement the next steps identified in the Walton Family Foundation's report, *Advanced Air Mobility Comes to Arkansas.*

2. Arizona

In 2021, the Arizona legislature established the Urban Air Mobility Committee. The Committee is charged with reviewing and recommending any needed revisions for current Arizona laws that could impact the urban air mobility industry; creating an outreach campaign to educate lawmakers and the public about urban air mobility technology and benefits; and collaborating with local governments to identify best practices for integrating urban air mobility into transportation plans. The study was expected to conclude at the end of 2022, but details on the results are not yet available.

3. California

In 2022, the California Department of Transportation (Caltrans) began an Air Digitization research project for UAS/AAM airspace corridors. Caltrans's Division of Aeronautics will use the study to evaluate the proposed siting and development of vertiports and airspace corridors. The project will also develop guidelines and best practices to aid state and local agencies in understanding, developing, and approving airspace corridors. Additionally, the project will identify any safety, equity, and environmental impacts a corridor will have on its local communities. The California State Transportation Agency, to which Caltrans reports, is currently conducting a study to define AAM integration for the state.

Los Angeles

With its significant levels of intercity helicopter operations, the industry has identified, Los Angeles, California as a location where AAM might first achieve commercially scalable operations. In December 2022, Urban Movement Labs—in partnership with the City of Los Angeles—published its study, *Integrating Advanced Air Mobility: A Primer for Cities* (Urban Movement Labs, 2022). Urban Movement Labs is a non-profit organization bringing together communities, local governments, and mobility innovators to test and bring to life new transportation technologies in the Los Angeles area. Additional study partners included the Los Angeles Department of Transportation, Los Angeles Department of City Planning, and eVTOL manufacturers Archer, Supernal (formerly Hyundai Urban Air Mobility), Volocopter, and Blade.

This collaboration was intended to build an understanding of the AAM landscape; engage community members; interface with industry; inform policy development; plan processes and regulatory decision-making associated with integrating urban aviation into existing city, regional, county, state, and national transportation networks; provide an understanding of how this new mobility technology would impact the citizens of Los Angeles; complement city-wide mobility goals; and provide a framework of equitable AAM transportation solutions for other cities to follow.

The study developed a conceptual flight plan to provide a path for integrating AAM. Three considerations and six actionable waypoints were established to guide their planning efforts. The considerations included engaging in federal policy development, contextualizing the current urban aviation landscape, and guiding AAM development through local policy.

The waypoints were as follows:

1. Determine Level of Involvement.
2. Leverage Executive Leadership and Resources.
3. Initial Research.
4. Engage and Inform Stakeholders.
5. Create a Vision.
6. Plan Strategically.

The study identified four common themes necessary to facilitate successful collaboration across jurisdictions—equity, safety, sustainability, and economic growth. As such, the city is prioritizing community-first engagement to ensure AAM-related infrastructure planning addresses local issues to create trust and accountability. The city's strategy also includes:

- Integrating AAM in efforts to eliminate transportation-related deaths and injuries while improving the health and well-being of its communities.
- Integrating AAM into the city's plan for a zero-emission transportation network to curb climate change and correct the harm of pollution on the city's most vulnerable populations.
- Integrating AAM into its economic development objectives for job creation.

4. Florida

In 2022, the Florida Department of Transportation's Division of Aviation commissioned an AAM Study (Florida Department of Transportation, 2022) to analyze the current state of the AAM industry in Florida and to develop a roadmap for AAM development (Florida Department of Transportation, 2022). The scope of the study—which focuses on commercial, passenger-carrying eVTOL aircraft and their support systems—included developing a policy framework for the emerging AAM industry to support the existing Florida Aviation System

Plan (FASP) and its future updates. The policy framework included land use compatibility, equity, transportation mode connectivity, safety, and security.

The study also developed recommended minimum standards for Vertiports and airport compatibility considerations for more than 30 airports. Compatibility considerations included an analysis of an airport's traffic pattern, instrument flight rules (IFR) approach procedures, controlled airspace, tall structures, and landfills. Additionally, potential infrastructure elements to accommodate eVTOL aircraft for each airport were identified. The second phase of the project established a working group consisting of state leaders, local governments, airports, industry, and academia. The working group is producing a report that will identify recommendations for the state to integrate AAM. The study concluded in 2023 with the publication of final study documents.

Other local AAM planning activities are being conducted in Miami and Orlando. A Concept of Operations (CONOPS) to evaluate services to connect the Miami International Airport (MIA) with the Miami Beach Convention Center was launched in March 2022 by Eve Air Mobility and a consortium of other AAM companies.

Orlando

In the fall of 2021, the City of Orlando began an AAM Transportation Plan to evaluate anticipated transportation, economic, environmental, and community impacts associated with AAM through a regional connectivity plan. The city has joined the World Economic Forum's Advanced and Urban Aerial Mobility Cities and Regions Coalition as a founding member. The coalition seeks to bring together cities and regions at the forefront of AAM to collaborate and share expertise while developing a range of solutions that can be adopted based on their respective needs. Additionally, NASA selected the City of Orlando as one of five government entities to participate in NASA's AAM aero-research partnership, which will work to define what it means to be a sustainable, resilient community with AAM as a significant new mode of public transportation.

In November 2020, eVTOL developer Lilium announced plans to develop a 2,000-mile air mobility network across the most populated areas of central and southern Florida. The community of Lake Nona in Orlando is proposed to be the first site of more than 10 vertiports expected to launch service in 2025. Lilium's air mobility network when completed will place the majority of Florida's 20+ million residents within a 30-minute drive of one of its vertiports.

5. Illinois

The Illinois Department of Transportation contracted with the Illinois Center for Transportation in 2021 to conduct an *Advancing Air Mobility in Illinois* study. The scope of the study included identifying potential scale, likely operational profiles, and safety considerations; addressing geographic operating environment diversity across Illinois; defining the potential influence AAM may have on the overall state transportation system; identifying infrastructure and facility needs; developing state-level policy and regulatory recommendations; and conducting a high-level assessment of potential economic, social, and environmental impacts. The study is pending publication.

6. Michigan

In 2022, Michigan Governor Gretchen Whitmer announced a partnership with the Government of Ontario, Canada to collaborate on a study to determine the feasibility of commercial drone corridors. Three proposed areas, the Grand Traverse Region, the Michigan Central Impact Area of Corktown Detroit, and the international connection between Michigan and Ontario will be analyzed. Study results are pending publication.

Additionally, in 2022, the Michigan Legislature proposed establishing a 27-member Advanced Air Mobility Study Committee through Senate Bill 795. Although the bill did not pass, it would have required the committee to review current state laws that could impact the AAM industry and propose revisions as necessary; identify potential laws in the state that will create jurisdictional consistency for AAM operations; foster public acceptance and awareness by creating an outreach campaign to educate the public and lawmakers; collaborate with local governments to identify the best ways to integrate advanced air mobility into transportation plans; and develop statewide policy recommendations on the operation, use, and regulation of unmanned aircraft systems in Michigan.

7. New Jersey

In June 2022, the National Aerospace Research and Technology Park (NARTP) released its study *New Jersey AAM Strategic Roadmap – The Road Ahead* (NARTP, 2022). NARTP is located on the FAA's William J. Hughes Technical Center campus and is adjacent to Atlantic City International Airport's designated Smart Airport Test Bed Facility. Here, NARTP works to advance aerospace sciences by creating an ecosystem of partnerships between industry, academia, and government to foster innovation and collaboration.

New Jersey's AAM roadmap identified three phases of development and outcomes. The Enable phase would occur in years 0–3, with the goal of establishing an AAM R&D Hub, identifying and establishing AAM test corridors, and conducting BVLOS cargo operations. It would also include establishing an AAM task force at the state level, identifying locations and infrastructure needs, and securing investment and partner resources. The Accelerate Phase, occurring in years 4–9, would transition to a Program Management Organization (PMO), partnering with operators to identify Concept of Operations (CONOPS) for passenger AAM, expand the R&D Hub to include design and testing, expand commercial cargo operations, and conduct the first passenger AAM flights. In years 10–15, the Scale phase would support an internationally integrated AAM R&D Hub supporting the AAM supply chain with self-sustaining passenger and commercial operations.

The study anticipated more than 25,000 new jobs would be created within 15 years of enabling the AAM industry. It also estimated that more than $150 million in additional annual state tax revenues would be generated by AAM-related jobs during this time. The study also cited the environmental benefits of AAM to include reducing emissions by 6,000 kilograms of CO_2 for 1,000 AAM passengers and estimated that AAM would provide three times greater access to food, jobs, and healthcare than traditional public transportation, thereby increasing access and equity.

8. North Carolina

In November 2021, the State of North Carolina awarded a $5 million grant to AeroX—a North Carolina-based non-profit organization focused on promoting the safe and efficient commercialization of UAS/AAM technologies—to design and develop an urban AAM system in Winston-Salem and Forsyth County. The grant allows AeroX to advance in building a UTM (Unmanned Traffic Management) system that will allow both uncrewed and crewed aircraft to fly safely in the low-altitude airspace in which UAS operate (below 400 feet). Additionally, in 2021, North Carolina created a grant program to offer AAM startups $50,000 grants to launch Winston-Salem-based AAM ventures.

9. Ohio

In August 2022, The Ohio Department of Transportation (ODOT) published the *Ohio AAM Framework* (Ohio Department of Transportation, 2022) study to prepare the state for the anticipated growth of AAM. The study's goal is to help position Ohio to be a leader in the industry; foster innovation responsibly and safely; create an economic advantage to attract new and high-paying jobs to the state; identify key considerations and constraints to inform the planning process for the state, its partners, and their stakeholders; and provide a recommended policy framework to assist key decision makers in preparing for, accommodating, and programming AAM into their regional plans.

Recommendations from the study included:

- Advance AAM workforce development.
- Work with local governments to develop AAM regulations.
- Encourage metropolitan planning organizations (MPOs) and regional transportation planning organizations (RTPOs) to incorporate AAM into their planning considerations.
- Develop and maintain relationships with the FAA to monitor, understand, and inform rulemaking related to AAM airspace, general aviation airspace, and infrastructure.
- Coordinate with other state agencies, partners, and stakeholders to develop statewide strategies and provide input to FAA and other federal agencies.
- Work with the state legislature to develop legislation to complement FAA regulations and avoid patchwork laws that would make AAM flight paths harder to design and vertiports harder to place.
- Share sample locality ordinance language and apply guidance consistently across jurisdictions.
- Collaborate with other state agencies and local jurisdictions for consistent supporting policies related to vertiport licensing and permitting, height restriction zoning, fueling, charging safety, and insurance regulations.
- Develop low altitude airspace design.
- Develop grant strategies to help in pursuit of funding that advances AAM priorities.

In June 2021, ODOT published its *Economic Impact Report for Advanced Autonomous Aircraft Technologies in Ohio* (Ohio Department of Transportation, 2021) study report. The study concluded that investing in AAM could generate an estimated $13 billion in economic impact over 25 years, including 15,000 new jobs, $2.5 billion in local, state, and federal tax revenues, and 1.6% GDP growth through 2045.

The UAS Center, a part of ODOT's FlyOhio program, is partnering with Ohio State University and others on a three-year research project along the 33 Smart Mobility Corridor to develop a low-altitude air traffic management system using passive radar. Their research will include using communication devices on both air and ground vehicles and will complement ongoing work to test autonomous and connected vehicles along the 33 Smart Mobility Corridor, a 35-mile stretch of highway between Dublin and East Liberty, Ohio. The UAS Center feels the use of passive radar for managing the low-altitude airspace could be a major key in finding a scalable system that can be deployed statewide. The study report is pending publication.

10. Oklahoma

The Oklahoma Aeronautics Commission is currently working in partnership with the Oklahoma Department of Transportation to develop a scope of work for a study on the development of AAM in the state. The study began in 2023.

11. Texas

In October 2022, the Texas Department of Transportation published a *Report and Recommendations of the Urban Air Mobility Advisory Committee* (Texas Department of Transportation, 2022). The committee was formed at the direction of the Texas Legislature to assess current state law regarding UAM and provide guidance on the development of its operations and infrastructure. The committee identified four focus areas of success for UAM including technology, airspace and infrastructure, safety and security, and commerce and community integration.

The Committee's recommendations included, but were not limited to:

- Encourage the development of an urban air mobility/advanced air mobility sandbox to provide a designated place—geographical or digital—where new technologies could be tested under liberal guidelines for a predetermined duration prior to commercial rollout to the public.
- Develop incentive programs to attract industry participation in the sandbox.
- Encourage state agencies to adopt a technology-neutral/open-architecture approach to UAM/AAM to allow for seamless integration of new technologies as they are deployed in new regions of the state.
- Identify areas where technology will drive standardizations.
- Provide statutory uniformity and standard definitions pertaining to unmanned aircraft operations and UAM/AAM in Texas law.
- Consider state funding to develop a UAM/AAM-centric research facility to test and evaluate technology and help guide data-driven public policy.
- Develop a statewide plan addressing potential locations for vertiports and associated infrastructure to help define the future operational environment.
- Provide technical assistance to local governments in integrating UAM/AAM in their communities.
- Develop minimum standards and safety management systems for vertiport operations, including the movement of passengers and goods as well as ground infrastructure.
- Ensure local government, law enforcement, and fire and emergency medical services have appropriate preparation, training, and safety practices associated with vertiport operations.
- Create a statewide primary point of contact to lead UAM/AAM workforce development efforts, lead public awareness and educational efforts, and collaborate with local, regional, state, and federal entities to encourage robust input and participation.

12. Utah

At the request of the Utah Legislature in 2022, the Utah DOT's Division of Aeronautics conducted the *Utah Advanced Air Mobility Infrastructure Study* (Utah Division of Aeronautics). The legislature directed that the study should identify assets (both current and in development) that would support AAM; identify assets required for full AAM implementation; identify the potential benefits and limitations of AAM implementation; examine the feasibility and options to implement a statewide AAM system; and review infrastructure funding mechanisms used or under consideration in other states.

The study found that Utah has the potential for more than $1.3 billion in economic growth by 2045 from AAM initiatives, and that the state has multiple infrastructure elements that could be utilized for AAM operations. These elements include current aviation infrastructure, parking facilities, a foundational electrical grid for charging electric vehicles, arobust communications network, and weather monitoring and reporting. Recommendations from the study included but were not limited to, creating a statewide innovation task force, initiating a public outreach and education campaign for AAM, developing sandboxes and innovation incubators, providing portions of public land at public facilities for early vertiport development, and establishing a statewide stakeholder innovation task force.

13. Virginia

The Virginia Innovation Partnership Corporation (VICP) and The Office of the Secretary of Commerce and Trade commissioned a study entitled *Virginia's Advanced Air Mobility Future* (Virginia Innovation Partnership Corporation, 2023). Published in January 2023, the study focused on the economic impact of AAM in the state along with an exploration of how the Commonwealth of Virginia could take on a national leadership role in the industry.

The study estimated AAM would generate $16 billion in new business activity in part by integrating AAM vehicles and related manufacturing in the state. It would add more than 10% growth to Virginia's existing aerospace sector, generate an additional $2.8 billion in local, state, and federal tax revenues, create more than 17,000 new full-time aerospace industry and other jobs, and bring employment and educational opportunities to all regions of the Commonwealth (including underserved and economically challenged areas).

In addition to the economic benefits identified, the study recommended seven actions and follow-on steps to support accelerating AAM adoption and foster future opportunity growth:

1. Appoint a Virginia AAM Executive Director to oversee, coordinate, and drive programs and policies to benefit the state's emerging AAM industry.
2. Fund (through a public-private partnership (PPP) plan), implement and operate minimum viable infrastructure (MVI) for air traffic management to enable the approval of beyond visual line of sight (BVLOS) operations in opportunity regions of the state.
3. Invest in multiple AAM development regions as test environments, utilizing local facilities including airports, heliports, test ranges, and companies and agencies currently active in each sector.
4. Attract and facilitate OEMs of AAM aircraft along with supporting supply chains.
5. Organize Virginia's public-use airports to ready themselves for regional air mobility (RAM) while supporting MVI services for AAM and serve as community engagement resources.
6. Continue expanding statewide STEM programs to advance future AAM workforce development.
7. Incorporate Washington, D.C. as part of Virginia's overall AAM business case and introduce a digital twins and immersive technologies living laboratory to accelerate AAM evolution and benefits.

14. Washington

The Washington Department of Transportation published the *Washington Electric Airport Feasibility Study* in October 2022 (Washington State DOT, 2020). The study was prepared by the University of Washington's Department of Civil and Environmental Engineering and analyzed the electrical grid near two regional airports—Paine Field and Grant County International Airport—to determine if they have the capacity to serve the potential energy and peak power needs of electric aircraft operations during the next one to two decades.

The study concluded that—based on capacities reported by the local electric utilities—the utility infrastructure serving these two airports has enough capacity at the neighboring substations to meet the demand for electricity over the next decade. The local utilities, while provisioning for the future demand for electric automobiles, had not previously considered the impacts of electric aircraft charging on their capacity. The study noted that to meet the charging requirements for electric aircraft, utility service upgrades will be necessary and will require additional investment in on-site airport transformers, rectifiers, and charging stations. It recommended that airports begin their preparations for electric aircraft by tracking industry developments as different models of electric aircraft gain certification; engaging with emerging electric aviation charging networks regarding their interest and ability to provide service at local airports; tracking state and federal clean energy grant opportunities; and encouraging local flight schools to consider electric training aircraft as a lower-cost alternative to traditional liquid-fueled airplanes.

3. AAM Use Cases for Georgia

The prospect of Georgia establishing an early foothold for AAM is promising, especially considering how many multinational aerospace companies—such as Delta Air Lines, Airbus, Gulfstream Aerospace, Lockheed Martin, and Raytheon—exist in the state. Aerospace products are Georgia's top export ($9.19 billion in 2021) and the state's second largest manufacturing industry, generating a $57.5-billion economic impact.

Since 2015, more than 40 facilities have located or expanded operations in Georgia, creating more than 2,500 jobs (Georgia Department of Economic Development, 2023). In addition to the existing concentration of industrial aerospace firms, Archer Aviation recently announced plans to build a 350,000-square-foot eVTOL factory in Covington, Georgia (Bristow, 2023).

Georgia has consistently been recognized as one of the most business-friendly states, garnering the number one ranking for 10 consecutive years from 2013-2023. This accomplishment means Georgia is uniquely placed to be a leader in the AAM space.

The primary application of AAM in Georgia will likely focus on transporting passengers and cargo using eVTOL aircraft, thereby reducing ground traffic congestion and the carbon footprint of intercity and local commuter travel as well as bringing other economic and environmental benefits. Potential AAM use cases in Georgia fall into four categories, as described in the following sections: air taxi, air cargo, public services, and personal/recreational services.

3.1 Air Taxi

AAM air taxi services are passenger operations that occur in urban, suburban, and rural areas (see **Figure 3-1)**. Currently, fixed-wing and helicopter aircraft face issues of noise and high operating costs when operating in this space. The eVTOL service providers look to mitigate these issues, offering aircraft that are purportedly quieter, more efficient, and less costly to operate. Proponents also tout that eVTOL aircraft will have higher adoption from the public than conventional aircraft. It is anticipated that early air taxi service routes could connect airports to city centers, while later stages could link various parts of a city together via multiple vertiports. eVTOL aircraft may offer one solution to congestion in cities with high traffic volumes, such as Atlanta.

Figure 3-1: NASA's Vision for Air Taxi

Source: (NASA, 2021)

The 2022 INRIX Global Traffic Scorecard notes that on average, traffic jams in the United States cost drivers an average of $869 annually in time lost. Atlanta was ranked the tenth worst city for traffic congestion, with drivers losing $1,257 in lost time, on average (INRIX, 2023). Other cities with significant congestion accounted for in the study included Chicago, New York City, and Miami, all of which are being targeted by early entrants for AAM air taxi services. With vertiports on parking garages or adjacent to multiple modes of transportation, easy access to AAM would likely serve to influence ridership. In the metropolitan regions of Atlanta, Macon, Savannah, and Columbus, AAM services could function as point-to-point transportation, offering drivers a timelier alternative to congested roadways.

Potential CONOPS for this type of passenger operation include:

1. Passenger service operation in the Atlanta Metro Area.

   This concept falls into the UAM subset of AAM, where passengers are transported at lower altitudes in urban areas, bypassing congested roads. Passengers would begin and end their trips at a vertiport—a defined area approved for the takeoff and landing of eVTOL aircraft. The vertiport could be at surface level or on top of a large building or existing vehicle parking garage.

2. Special event mobility.

   Special events like the Masters Tournament in Augusta bring tens of thousands of spectators to the city to watch pro golfers compete for the coveted championship title. Transporting people to and from this event would be similar to regular passenger service operations, but would exist only around the time frames of the event itself.

3. Rural commuter service.

   This concept would fall into the category of regional air mobility (RAM), another subset of AAM that includes eVTOL operations to rural communities where commercial air service does not usually exist. Many rural towns have a local airport, often underused, that can serve as the origination or termination point of a flight connecting to a more populous area.

4. Passenger service within Georgia connecting to Hartsfield-Jackson Atlanta International Airport.

   This RAM concept would serve people needing transportation to the Airport for a flight on a conventional airliner, enabling them to avoid high parking fees and commute time. The airport hosts more than 70 airlines with routes to 42 countries, making it one of the busiest in the world. In 2022, the airport had 724,145 total aircraft operations and transported 93,699,630 passengers. With this much traffic, a RAM concept using eVTOL aircraft could be successful.

The detailed version of these CONOPS conducted as part of this study can be found in the **GDOT AAM Study CONOPS Report.**

The use cases mentioned above offer insight into the potential demand that may exist for eVTOL services in different areas of Georgia. Historically, air taxi services have used small, fixed-wing aircraft and helicopters to transport individuals from one location to another. Fixed-wing aircraft are limited by the need for airports, which can constrain their use for intercity travel. According to FAA records, air taxi operations at Georgia airports in 2022 totaled more than 117,000, with most of the service (approximately 37 percent) going to or from Hartsfield–Jackson Atlanta International Airport (see **Table 3-1**). It is anticipated that with lower-operating-cost aircraft like the eVTOL, the number of air taxi operations could increase.

Table 3-1: Taxi Operations at Georgia Airports (2022)

LOC ID	Name	Air Taxi Operations
ABY	Southwest Georgia Regional	2,279
AGS	Augusta Regional	7,027
AHN	Athens-Ben Epps	2,448
ATL	Hartsfield–Jackson Atlanta International	43,819
CSG	Columbus	2,771
FTY	Fulton County Executive	4,595
LZU	Gwinnett County	3,882

LOC ID	Name	Air Taxi Operations
MCN	Middle Georgia Regional	1,746
PDK	DeKalb-Peachtree	26,474
RYY	Cobb County International	6,996
SAV	Savannah/Hilton Head International	15,132
SSI	St Simons Island Airport	2,109
Total:		**119,278**

Source: (Federal Aviation Administration, 2023)

Unlike fixed-wing aircraft, helicopters require a smaller footprint for their operations, which makes them more versatile. Historically, widespread adoption of helicopter air taxi services has largely been limited because of the cost of the service and the noise levels associated with the aircraft.

According to the FAA, there were approximately 1,800 helicopter operations recorded at Georgia's public-use airports in 2022. These operations are spread throughout airports in the state, but the top five airports for helicopter operations are shown in **Table 3-2**.

Table 3-2: Top Ten Georgia Airports for Helicopter Operations

#	Airport	Total Operations
1	ABY - Albany	251
2	MCN - Macon	168
3	AGS - Augusta	132
4	WDR - Winder	130
5	SAV - Savannah	128

Sources: (Federal Aviation Administration, 2023)

3.2 Air Cargo

Uncrewed aerial systems (UAS) are a form of AAM currently used successfully in cargo and package delivery. These operations expedite the last-mile connection, moving cargo from distribution centers to the delivery location. Conversely, air cargo use cases for eVTOL aircraft would cover the middle-mile of the logistics supply chain, connecting factories or airports to distribution centers (see **Figure 3-2**). Currently, this leg of the transportation journey is typically accomplished with cargo vans and box trucks.

United Parcel Service of America (UPS) is headquartered in Atlanta, GA, and is the third largest air cargo carrier in the world according to IATA World Air Transport Statistics (WATS) data for 2021.

Figure 3-2: NASA's Vision for Air Cargo

Source: (NASA, Kyle Jenkins, 2023)

UPS has been an early innovator in deploying and driving advances in UAS. In 2019, UPS and drone company Matternet partnered with WakeMed Hospital in Raleigh, North Carolina, for the first regular commercial flights of drones carrying medical products. The WakeMed drone program intends to improve the speed of medical deliveries at a lower cost and initially will transport medical samples from a medical park to the main hospital building for lab testing (Wire Staff, 2019).

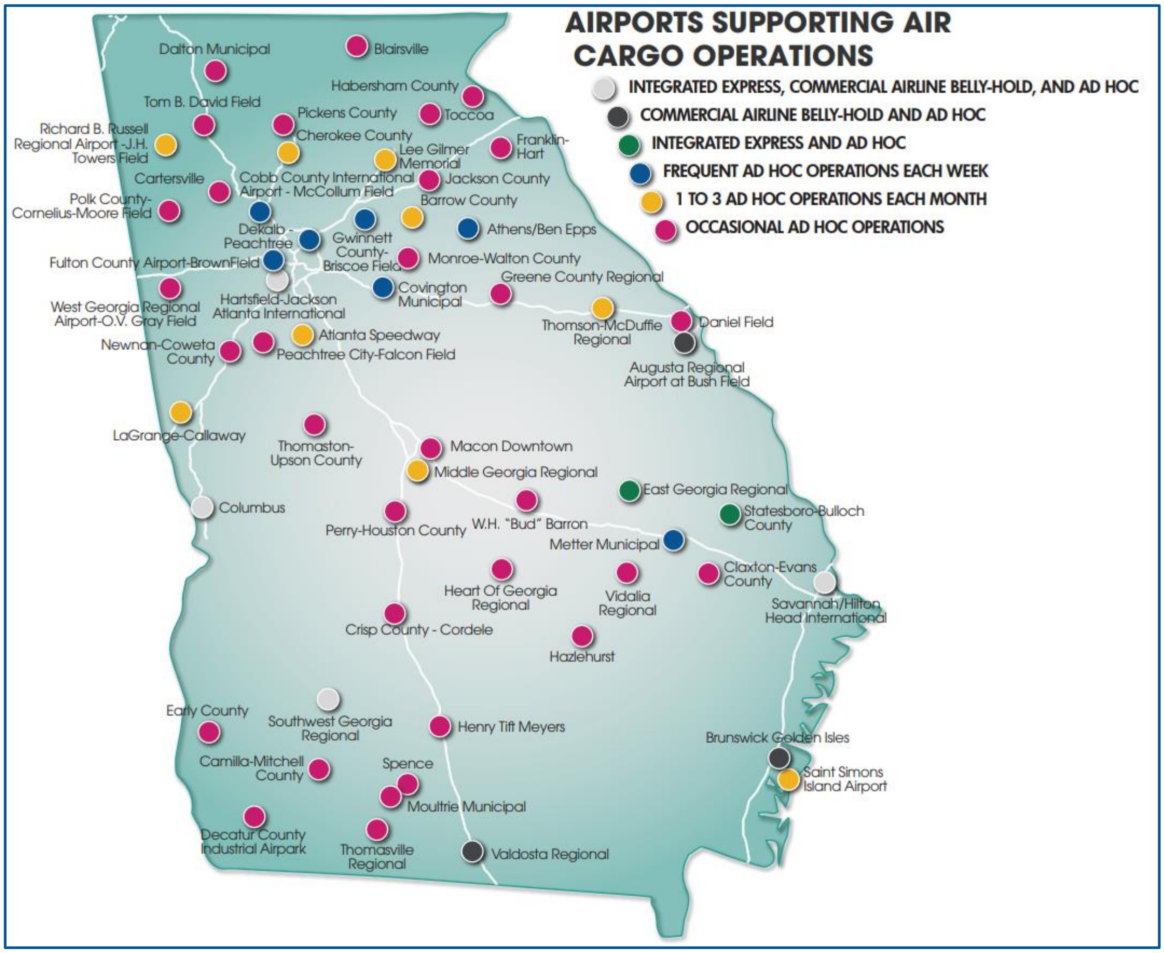
In August 2020, UPS—in partnership with CVS, the nation's largest healthcare solutions provider and pharmacy—began using drones to deliver prescription medicines to The Villages, Florida. The Villages is the largest retirement community in the nation and is home to more than 135,000 residents (UPS, 2020). In April 2021, UPS subsidiary UPS Flight Forward received the first FAA Part 135 certification to operate a drone airline and is currently operating daily, revenue-generating flights with drones. The FAA certification also enables UPS Flight Forward to fly payloads of up to 7,500 lbs., either with an operator or autonomously.

Additionally, that same month, UPS announced plans to purchase 10 eVTOL cargo aircraft from BETA Technologies with an option to purchase up to 150. BETA's aircraft will supplement UPS's air services, specifically in small and mid-sized markets. The first 10 eVTOL aircraft are scheduled for delivery in 2024. This move could see eVTOL aircraft replace some UPS cargo vans on certain trips, especially for time-sensitive deliveries. To support their cargo customers, BETA completed the installation of a charging station for their eVTOL aircraft at the Augusta Regional Airport (AGS) in March 2023 and has announced proposed additional charging infrastructure for their network at the DeKalb-Peachtree Airport in Atlanta, Albany Regional Airport, Savannah/Hilton Head Airport, and the Ware County Airport in Waycross.

FedEx Express also has plans to add AAM aircraft to its fleet—specifically the Chaparral, an autonomous hybrid-electric eVTOL aircraft by Elroy Air. FedEx Express conducted a first-of-its-kind test of Elroy's cargo-carrying autonomous eVTOL in 2023. The plan is for this eVTOL to ferry goods between FedEx sorting locations. The aircraft's ability to carry 300–500 pounds of cargo for up to 300 miles makes this a likely scenario (Jviation, A Woolpert Company, 2022, p. 6).

In 2022, GDOT finalized a Statewide Air Cargo Study, which provided an overview of the current air cargo industry in Georgia and recommended investments at air cargo facilities to support the system's needs. **Figure 3-3** shows current air cargo activity at Georgia airports. Fifty-eight of the 103 airports in Georgia accommodate some type of air cargo operations. Scheduled service takes place at six Georgia airports, including Southwest Georgia Regional, Hartsfield-Jackson Atlanta International, East Georgia Regional, Columbus, Statesboro-Bulloch County, and Savannah/Hilton Head International. At those airports, annual air cargo tonnage is expected to nearly double from 2019 to 2040 (Georgia Department of Transportation, 2022).

Figure 3-3: Georgia's Current Ad Hoc and Scheduled Air Cargo Activity



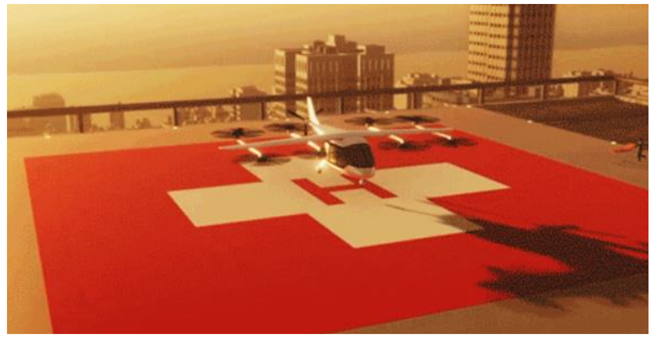
Source: (Georgia Department of Transportation, 2022)

The study identifies and recommends approximately $103.7 million in improvements for airports served by integrated express carriers and suggests establishing an air cargo working group to keep Georgia at the forefront of the air cargo industry. It also identifies the statewide impact of emerging technologies that characterize the air cargo industry, such as VTOL, electric aircraft, and UAS. In addition to documenting UPS and FedEx AAM activity, the study additionally highlights a partnership between DHL Express and Eviation, a manufacturer of all-electric fixed-wing feeder aircraft (Georgia Department of Transportation, 2022).

3.3 Public Services

Public service agencies may be one of the first sectors to embrace eVTOL aircraft. With purported lower maintenance costs and greater reliability than helicopters, eVTOL aircraft could supplement current public services performed with ambulances, firetrucks, and helicopters. Rapid first response to any emergency adds value, and AAM is viewed as more cost-efficient compared to traditional aircraft (see **Figure 3-4**).

Figure 3-4: NASA's Vision for Air Ambulance



Source: (NASA, Kyle Jenkins, 2023)

BETA Technologies got its start when United Therapeutics, a biotech firm founded to develop artificial organs, recognized the potential for eVTOLs to support organ transfers and partnered with BETA to develop eVTOL aircraft. Thus, BETA includes organ transplant airlifts as one of its core reasons for existence (Bogaisky, 2021). Unither Bioelectronics, a wholly-owned subsidiary of United Therapeutics, is also working with eVTOL manufacturers to harness the potential efficiency and safety of AAM to improve transplantable organ transportation (Unither Bioelectronics).

In Georgia, eVTOL aircraft may be able to provide greater and more affordable access to healthcare services in rural parts of the state. In areas like the Atlanta metro highways, eVTOLs could expedite access to emergency lifesaving care when ground transport is limited by road congestion. According to NASA's recent white paper on eVTOL use in public services, eVTOL aircraft have the potential to "become an essential tool to Public Service agencies around the world in applications such as firefighting, public safety, search and rescue, disaster relief, and law enforcement" (Pavel, Smith, Doo, & Tsairides, 2021, p. 2).

eVTOLs could also be especially valuable in fighting fires in Georgia, as forest fires can plague the two-thirds of the state that is forested (Capitol Beat News Service, 2022). Several eVTOL OEMs are looking at firefighting options for their aircraft. Senator Bill Nelson, NASA Administrator, indicated that AAM "aircraft can be a game-changer for emergency response and rescue operations" (Reed, 2022). Joby Aviation's CEO suggested that drones and eVTOL aircraft would be capable of fighting fires more efficiently and would avoid impact on the environment while doing it (Head, 2022).

There are also military uses for eVTOL in the public sector. The innovation arm of the US Air Force, AFWERX, launched Agility Prime in April 2020 to accelerate development of the commercial eVTOL aircraft industry and enable a hardy and sustainable distributed logistics system (Air Force Research Laboratory Public Affair, 2022). Agility Prime has worked with numerous companies, including LIFT, BETA Technologies, Kittyhawk, and Archer Aviation. In 2021 and 2022, the Agility Prime program made considerable progress, with four company recipients going so far as to achieve military airworthiness. In 2023, the goal is to begin eVTOL operations with an initial use case (Reed, 2022). Military eVTOL will likely be used for last-mile logistics, frontline re-supply, medivac, and ship-to-shore logistics.

3.4 Personal/Recreational

Some OEMs are developing eVTOL aircraft under the "ultralight category" of Federal Aviation Regulation (FAR) Part 103. This regulation avoids many of the complex FAA certification hurdles and pilot training requirements. However, it comes with its own limitations, including the inability to fly over congested areas. Accordingly, this segment of AAM will likely be used for private and recreational purposes. The aircraft HEXA, created by LIFT, is an ultralight eVTOL capable of transporting one person over short distances and is expected to be used as a type of adventure experience where users can rent and fly a HEXA in a controlled, geospatially-mapped, and fenced flight area. The Jetson One is another ultralight category aircraft aimed at the personal market.

Georgia is also popular with glider pilots and skydivers, and this may translate to increased opportunities for emerging recreational aviation. Personal eVTOL aircraft may also be seen on farms and ranches where the terrain makes the land difficult to traverse by automobile.

3.5 Conclusions

Georgia is a promising location for a range of AAM operations and applications, including air taxi, air cargo, public services, and private/recreational services. Air taxi services provide a valuable solution for customers looking to avoid heavy traffic in the Atlanta metro area and beyond. Additionally, Georgia's airports already have a strong air cargo presence, with UPS making significant investments in AAM. Furthermore, eVTOL technology has the potential to enhance public service missions throughout the state by supplementing current ambulance, firetruck, and helicopter services, and facilitating personal travel for those navigating difficult terrain. This, in conjunction with Georgia's established aerospace industry, positions the state well for success in the AAM sector.

4. Best Practices for AAM Landing Area Regulation and Safety

Federal and state governments have a vital role to play in developing a regulatory framework for eVTOL landing areas. While the FAA does not regulate land uses, they do certify airports that serve commercial air carriers and provide minimum standards for general aviation landing areas serving airplanes, helicopters, and eVTOL aircraft. Many of those standards become mandatory if the airport is federally obligated through FAA grant assurances.

The State of Georgia currently has statutory responsibilities for inspecting, licensing, and establishing guidelines for minimum safety standards for certain open-to-the-public airports. This chapter provides an overview of federal guidance for AAM landing areas, state minimum standards, and licensing protocols for landing facilities in Georgia. Additionally, it identifies potential gaps in state protocols for vertiports through a gap analysis and provides recommendations for best practices to inform AAM landing area regulations in the state.

4.1 Existing Federal Guidance

In 1991, the FAA published Advisory Circular (AC) *150/5390-3 Vertiport Design*, which covered airside, airspace, marking, lighting, NAVAIDs, landside, and tiltrotor facilities at airports. While the AC provided guidance related to military tiltrotor technology at the time, the civil tiltrotor did not make it to the commercial market, and the AC was canceled on July 28, 2010.

Today, many of the eVTOL aircraft have similar designs to the military tiltrotor aircraft of the 1990s, but since AC *150/5390-3 Vertiport Design* was canceled, OEMs began using the heliport design AC *150/5390-2C*—now updated to *-2D*—as a guide for developing eVTOL infrastructure. However, the FAA's heliport design AC did not fully accommodate the unique design considerations for vertiports serving the eVTOL aircraft currently being developed. These unique considerations include but are not limited to, thermal impacts to runaways associated with batteries, hazardous materials from battery leaks or fires, aircraft rescue and firefighting to prevent electrical fires, electrical charging stations, and eVTOL rotor downwash and outwash. Because of the unique designs and issues associated with emerging eVTOL aircraft, the FAA initiated research in 2020 to support the development of a new AC for vertiport design.

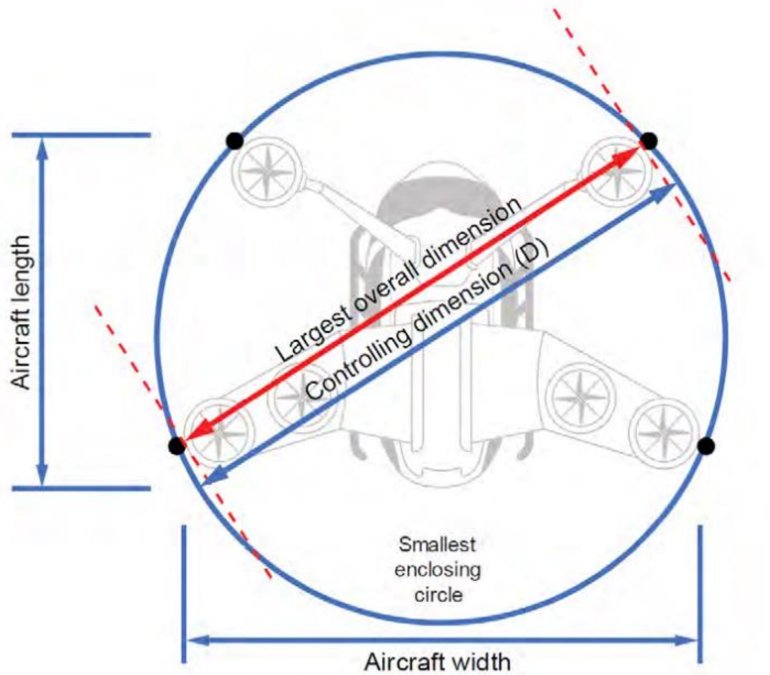
The aim of the FAA's research is to establish the minimum safety and design standards for the development of vertiport facilities that will be used for passenger and cargo operations by eVTOL aircraft. The evaluation criteria used to determine the vertiport design standards will include the critical dimensions of an aircraft, its maximum gross takeoff weight, and its performance capabilities. The research includes an industry request for information (RFI) regarding VTOL aircraft design and specifications, CONOPS, and takeoff and landing profiles. It also includes conceptual/operations testing and simulation of conceptual vertiports.

To provide interim guidance until a full AC can be developed, the FAA published Engineering Brief (EB) 105, Vertiport Design in September 2022 as presented in the following section. The EB is currently limited to visual meteorological conditions for a design aircraft that is no more than 50 feet wide by 50 feet long, uses distributed electric propulsion power by battery packs, has a pilot on board, can hover out of ground effect, and departs and lands vertically.

Overview of EB 105

EB 105 is the only guidance given for vertiport design at this time. However, it provides the basic minimum safety elements needed for a vertiport, which, in theory, are not expected to change with different aircraft power sources. The minimum elements needed for a vertiport's landing geometry are based on the controlling dimension of the aircraft, which under the EB can be no more than 50 feet. The controlling dimension (D) is the diameter of the smallest circle enclosing the aircraft projection on a horizontal plane while the aircraft is in the takeoff or landing configuration, with rotors/propellers turning, as applicable. **Figure 4-1** shows the landing geometry of the vertiport.

Figure 4-1: Controlling Dimension of a Vertiport



Source: (Federal Aviation Administration, 2022)

The minimum elements of a vertiport consist of the following items, as shown in **Figure 4-2**:

Touchdown and Liftoff Area (TLOF)

The TLOF is a generally paved, load-bearing area centered in the final approach and takeoff area, on which the aircraft performs a touchdown or liftoff. EB 105 Brief specifies that a TLOF should be 1D of the design aircraft. To accommodate the largest aircraft that could use the EB (one with a controlling dimension of 50 ft.), a TLOF would be 50 feet in diameter.

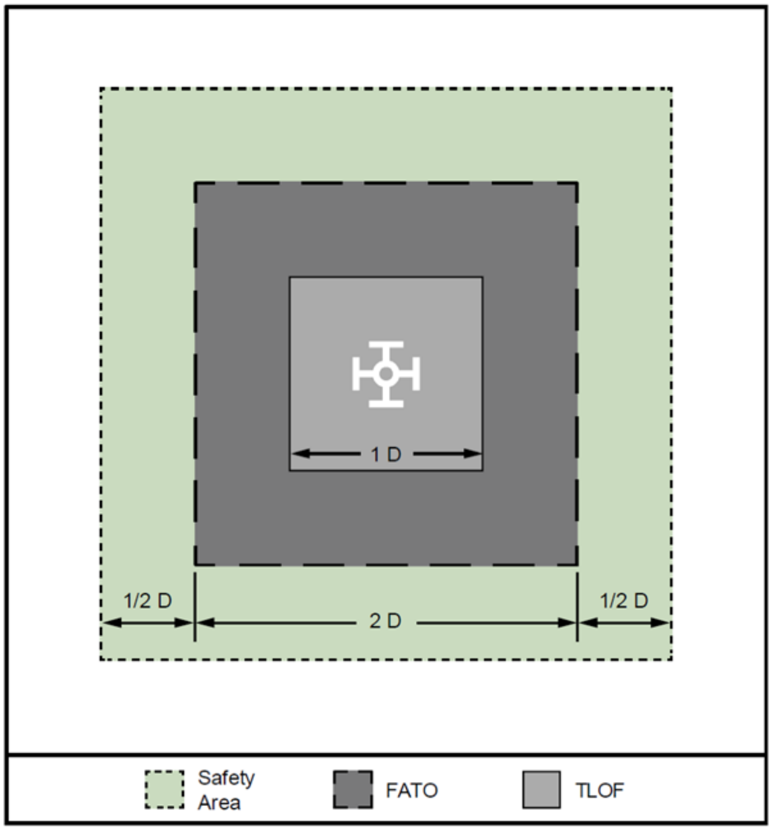
Final Approach and Takeoff Area (FATO)

The FATO is a defined, load-bearing area over which the aircraft completes the final phase of the approach to a hover or a landing, and from which the aircraft initiates takeoff. EB 105 specifies that a FATO should be 2D of the design aircraft. Based on the largest aircraft that can use the EB, a FATO would be 100 feet in diameter. Two ingress and egress paths are required, as close to reciprocal as possible but at least 135 degrees apart. See the Imaginary Surfaces section below for more details.

Safety Area (SA)

The SA is a defined area surrounding the FATO intended to reduce the risk of damage to aircraft accidentally diverging from the FATO. EB 105 specifies that a Safety Area should be 3D of the design aircraft. The SA would need to be 150 feet in diameter.

Figure 4-2: Relationship and Dimensions of TLOF, FATO, and Safety Area

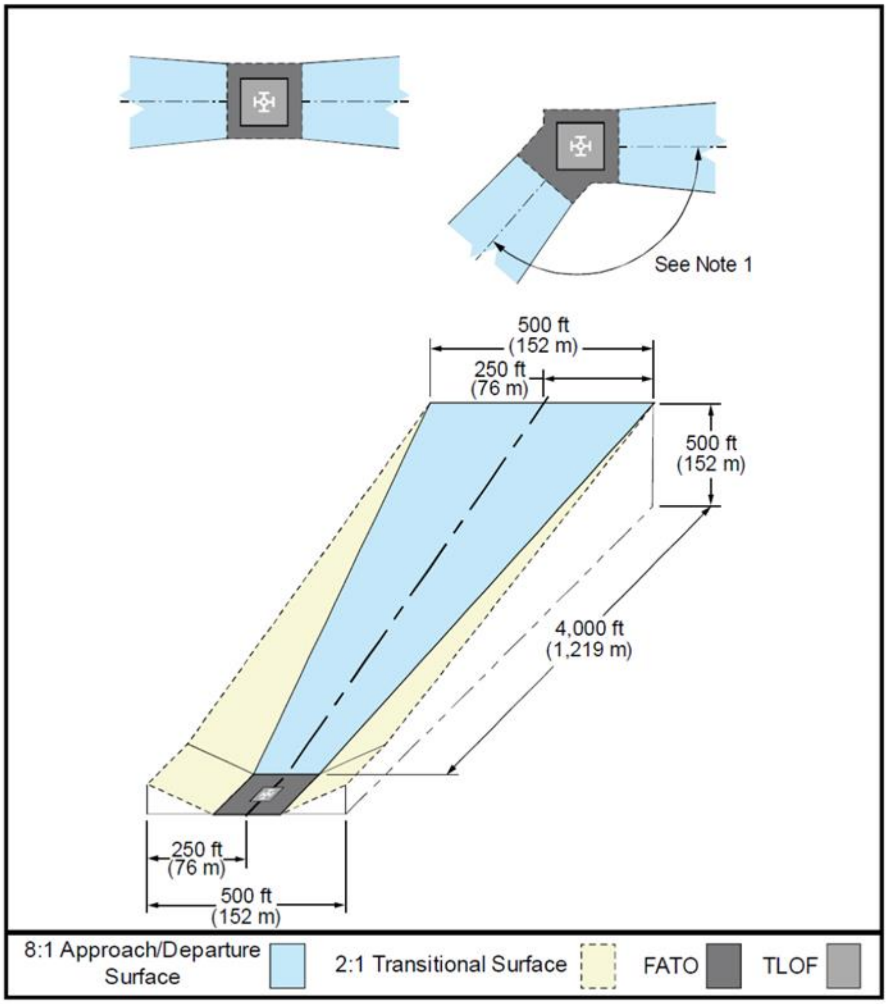


Source: (Federal Aviation Administration, 2022)

Imaginary Surfaces

Imaginary surfaces are the imaginary planes defined in 14 CFR Part 77, Safe, Efficient Use, and Preservation of the Navigable Airspace. Centered around the FATO and the approach/departure paths, these planes are used to identify objects that require notice to, and evaluation by the FAA. There are three relevant surfaces presented in the Engineering Brief as shown in **Figure 4-3**. The primary surface is a horizontal plane coinciding with the size, shape, and elevation of the FATO. The approach/departure surface begins at each end of the primary surface and extends outward and upward at a slope of 8:1 horizontal units to vertical units for a distance of 4,000 feet and a width of 500 feet. The transitional surfaces extend outward and upward from the lateral boundaries of the primary and approach/departure surface at a slope of 2:1 horizontal units to vertical units for 250 feet horizontal from the centerline of the primary and approach/departure surfaces.

Figure 4-3: Visual Flight Rule (VFR) Vertiport Imaginary Surfaces



Source: (Federal Aviation Administration, 2022)

Currently, any sponsor of a federally obligated airport pursuing an eVTOL vertiport or supporting infrastructure must update its Airport Layout Plan (ALP) with the FAA, conduct the applicable environmental review required by the National Environmental Protection Act (NEPA), and submit an FAA Form 7460, Notice of Proposed Construction or Alteration, for an airspace determination. Non-federally obligated airport sponsors must submit FAA Form 7480-1, Notice for Construction, Alteration, and Deactivation of Airports, at least 90 days prior to the construction of a vertiport.

4.2 Comparative State Actions

Across the country, states are working to understand how their laws, rules, and regulations pertain to AAM, where changes or additions to those laws will be needed, and where the state can provide guidance to local governments. As noted in **Chapter 2**, at least twenty states have or are undertaking some type of AAM planning effort. Among those states, several have published reports including recommendations or best practices for the safety of AAM landing areas. Brief overviews of these recommendations are listed in the following sections:

1. Florida

In 2022, the Florida Department of Transportation's Division of Aviation commissioned an AAM Study (Florida Department of Transportation, 2022) to analyze the current state of the AAM industry in Florida and to develop a roadmap for AAM development. The report identified best practices for local governments as they relate to AAM landing areas.

- Review existing zoning ordinances for compatibility with AAM.
- Map out existing aviation facilities, including airports and heliports, as well as flight corridors and imaginary surfaces to identify potential conflicts.
- Identify incompatible land uses and evaluate existing urban noise levels.
- Develop community-first policies for vertiports and update relevant zoning.

The second phase of the project established a working group consisting of state leaders, local governments, airports, industry, and academia. The working group has produced a report that will identify recommendations for the state to integrate AAM.

2. Ohio

In August 2022, The Ohio Department of Transportation (ODOT) published the *Ohio AAM Framework* (Ohio Department of Transportation, 2022) study to ready the state for the anticipated growth of AAM and position Ohio to be a leader in the industry. The study identified several best practices as they relate to the safety of AAM landing areas, including:

- Work with the state legislature, metropolitan planning organizations, and localities to complement FAA regulations and avoid patchwork laws that would make AAM flight paths harder to design and vertiports harder to place.
- Work with airport and airport zoning boards to educate and inform them on AAM in order to prepare and protect current and future AAM activities.
- Work with the Department of Public Safety (DPS) to discuss the need to frame out regulations regarding safe operation, regulatory compliance, and enforcement as AAM evolves and airspace access becomes commonplace for individuals.
- Collaborate with other state agencies and local jurisdictions for consistent supporting policies related to AAM in areas such as:
    - Licensing/permitting processes for airports/vertiports.
    - Height zoning around airports/vertiports.
    - Fueling and charging safety (i.e., national, state, and local fire code coordination).
    - Insurance regulations (Department of Insurance).

3. Texas

In October 2022, the Texas Department of Transportation published its *Report and Recommendations of the Urban Air Mobility Advisory Committee* (Texas Department of Transportation, 2022). The committee was formed at the direction of the Texas Legislature to assess current state law regarding UAM and to provide guidance on the development of UAM operations and infrastructure. The report identified numerous best practices relating to AAM landing areas, including the following:

- Provide consistency across Texas law by creating statutory uniformity and standard definitions pertaining to unmanned aircraft operations and urban air mobility/advanced air mobility.
- In collaboration with the appropriate federal entities, work to encourage the development of minimum standards/safety management systems for vertiport operations, including passenger and goods movements and ground infrastructure.
- Support development of standardizations at the federal level and within the industry as technology develops/changes so safety is prioritized as the technology matures.
- Direct the Texas Department of Transportation to review existing state aviation standards and guidelines, airport facility planning, and compatibility guidance to ensure they apply to urban air mobility/advanced air mobility.
- Encourage state-level cooperation with local governments to ensure appropriate preparation, training, and safety practices associated with vertiport operations, including law enforcement, fire service, and emergency medical services associated with traditional aviation and advanced air mobility aircraft operations.

4. Utah

At the request of the Utah Legislature in 2022, the Utah DOTs Division of Aeronautics conducted the *Utah Advanced Air Mobility Infrastructure Study* (Utah Division of Aeronautics). The study provides a list of recommendations for the state legislature to consider, many of which pertain to the safety and regulation of AAM landing areas. These include:

- Defining a plethora of terms in state law relating to AAM, including vertiport, aerial transit corridor, and unmanned traffic management.
- Establishing a formal advanced air mobility program under the jurisdiction of the Division of Aeronautics.
- Considering ensuring municipalities develop language inclusive of VTOL operations within their zoning ordinances.
- Considering requiring municipalities to adopt language to protect the navigable airspace around vertiports by establishing local “vertiport hazard areas.”
- Considering ensuring that long-range transportation planning incorporates land-use plans for future potential vertiport sites.

Last, the report suggests establishing a statewide mobility innovation task force to initiate effective collaboration between the relevant state agencies tasked with regulating AAM.

The planning efforts undertaken by these states provide a framework for Georgia’s understanding of the state’s role in regulating AAM facilities. The next sections of this chapter outline Georgia’s existing regulation of airports, gaps in that process as they relate to AAM landing areas, and best practices for Georgia’s regulation of these facilities.

4.3 Georgia's Minimum Standards and Licensing and Inspection of Airports

In Georgia, the state's role in open-to-the-public landing facilities involves three main components: airport inspection, airport licensing, and the development of minimum standards for these facilities. The state statutes and administrative rules and regulations that provide the legal framework for these components are listed below:

- **Official Code of Georgia (OCGA) § 32-9-8: Licensing Airports**: This section of the state code defines the term "airport" as follows:

  Any area of land, water, or mechanical structure which is used for the landing and takeoff of Aircraft, and is open to the general public, as evidenced by the existence of a current and approved Federal Aviation Administration Form 7480-1 or any successor application, for such use without prior permission or restrictions and includes any appurtenant structures and areas which are used or intended to be used for airport buildings, other airport facilities, rights of way or easements; provided, however, that the term "Airport" shall not include the following facilities used as airports:

  1. Facilities owned or operated by the United States or an agency thereof except for some joint-use airports;

  2. Privately owned facilities not open to the general public when such facilities do not interfere with the safe and efficient use of airspace of a facility for which a license or an Airport Operating Certificate issued under 14 C.F.R. Part 139 of the Regulations of the Federal Aviation Administration, or any successor regulations, has been granted;

  3. Facilities being operated pursuant to 14 C.F.R. Part 139 relating to certification requirements for airports serving scheduled air carrier operations, or any successor agency of the United States government (State of Georgia, 2021).

  This code outlines the criteria and legal justification for airport licensing and grants authority to GDOT to establish rules and regulations for the licensing of such facilities. Any changes to this statutory language require formal action by the state legislature.

- **Chapter 672-9 Rules and Regulations for Licensing of Certain Open-to-the-Public Airports:** This administrative rule is promulgated by GDOT under the authority granted in OCGA § 32-9-8: The Rule provides the statutory definition of an airport and adds additional aeronautical definitions for heliports and open-to-the-public airports. The rule defines a heliport as "*An area of land, water, or structure used or intended to be used for the landing and takeoff of Helicopters*," and an open-to-the-public airport as *"An Airport that is publicly or privately owned which is open and available for use by the general flying public"* (Georgia Rules and Regulations, 2023).

  The airport licensing rules and regulations define the minimum standards for obstruction-free approach paths, primary surfaces, runway safety areas, and other key airport safety requirements, similar to the federal requirements described in FAR *Part 77 Safe, Efficient Use, And Preservation Of The Navigable Airspace* and FAA *AC 150-5300-13 Airport Design*. The rule provides those minimum standards and outlines the process for the issuance of an airport license and the frequency with which licensed airports are inspected. A change to these rules and regulations can be amended without involvement by the state legislature.

Current regulation for landing facilities in Georgia is based on these laws, rules, and regulations. The following section presents a gap analysis that identifies potential gaps in regulation for AAM landing facilities.

4.4 Gap Analysis

Minimum Standards

While the definition of an airport in Georgia Code Title 32 would include a vertiport, Chapter 672-9 does not specifically include the term "vertiport" or its definition. While heliports serve as the closest type of aviation infrastructure to vertiports, the FAA has determined that the differences between traditional fossil fuel-powered helicopters and emerging eVTOL aircraft are enough to warrant a new AC to cover the facilities they will operate in.

Neither the heliport design AC nor Georgia minimum standards cover many of the critical safety considerations needed for eVTOL aircraft, such as charging infrastructure, management of thermal runaway, aircraft rescue and firefighting, and high-speed data. Currently, FAA Engineering Brief 105 represents the domestic design guidance for vertiports that GDOT should plan to follow until the FAA issues a full vertiport design AC.

Licensing and Inspections

Chapter 672-9, Rules and Regulations for Licensing Certain Open-To-The-Public Airports, outlines the process for licensing and inspecting qualifying airports, which includes heliports, seaplane bases, etc. Airports meeting the definitions outlined in this rule must apply for a license to operate prior to opening the facility and thereafter every two years. Airports are issued a license after an inspection determines the facility meets Georgia's published minimum standards. Adding a section on vertiport to Chapter 672-9 would extend the terms of the state's licensing and inspection requirements to these facilities. Vertiports, like Georgia's existing airports, will range in size and operational complexity. Vertiports will also have differing support facilities based on the use cases and operations they are supporting.

Vertiports that are open to the flying public would meet Georgia's definition of an open-to-the-public airport and would be subject to licensing, inspection, and minimum standards as defined in Chapter 672-9. One example of this type of facility would be a publicly-owned vertiport built at a MARTA stop to serve paying passengers.

Vertiports that are privately owned and for use by a specified private entity would not meet Georgia's definition of an open-to-the-public airport and would not be subject to licensing, inspection, or minimum standards as defined in Chapter 672-9: One example of this type of facility would be a vertiport built and operated by a single cargo company at a privately-owned sorting facility.

Classifying vertiports that are privately owned and support commercial eVTOL operations by one or numerous eVTOL operators is not as straightforward. The deciding factor for whether a landing facility is open to the public can be based on whether prior authorization is required for an aircraft to land at the facility or not. It can also be based on whether the general public is being solicited in any way to use it. (E.g., do the owners advertise flight training, aircraft rental, sale of fuel, or carrying passengers for hire?)

Historically, this has not presented a dilemma for many states because private use facilities typically do not generate high-tempo, high-volume commercial operations. One example of a privately-owned, commercial-use facility is a vertiport that is owned and operated by a private entity but supports air taxi services by one or more eVTOL operators. These facilities may warrant some level of licensing, inspection, and minimum standards to ensure adequate safety for the public, especially if a facility is advertising these services. GDOT should determine if the state has an obligation to provide for the safety of the traveling public at such facilities.

The examples of these different types of vertiports and whether they are subject to be licensed and inspected under current Georgia Rules and Regulations are shown in **Table 4-1.**

Table 4-1: Vertiport CONOPS and Licensing Eligibility

Vertiport Concept of Operations	Example	Subject to Licensing/Inspection
Publicly-owned vertiport open to the public for air taxi services	Vertiport built at a MARTA stop that serves air taxi eVTOL and their passengers	Yes
Privately-owned vertiport for use only by a specified private entity	Privately owned vertiport at private cargo sorting facility	No
Privately-owned vertiport supporting commercial air taxi eVTOL operations by an eVTOL company/companies that allows the public to book flights	Privately owned vertiport in downtown Atlanta where the public is being solicited to use an air service	Yet to be determined

4.5 Best Practices and Conclusions

Along with several takeaways from the gap analysis for both minimum standards and the licensing and inspection process for AAM landing facilities, this chapter contains additional best practices derived from other states. This section details those best practices, and additional recommendations for a state program that licenses and inspects vertiports are featured in the AAM Action Plan section of this study. Additional recommendations for local governments can be found in the Community Guidebook and Toolkit section.

Minimum Standards

Georgia Code Title 32-9-8's existing definition for an airport is broad and would include any future vertiports. Rules and Regulations Chapter 672-9, however, includes definitions for subcategories of airports (like heliports, for example), so it would follow that vertiports, a new subcategory of airports, should also be defined in the Chapter.

To promote and maintain a safe ecosystem of vertiports, Georgia should modify Rules and Regulations Chapter 672-9 to the following:

- Adopt the definition of eVTOL aircraft as found in FAA EB 105, or any successor EB, or any subsequent FAA AC on vertiport design.
- Adopt the definition of vertiport as found in EB 105, or any successor EB, or any subsequent FAA AC on vertiport design.
- Adopt the minimum standards found in EB 105 for vertiports or any subsequent FAA AC on vertiport design.

Licensing and Inspections

Georgia's current process for licensing and inspecting open-to-the-public airports would apply to many of the vertiports that could surface in Georgia should eVTOL aircraft be embraced by the general public, but more clarity is needed.

Listed below are some best practices to consider adopting to ensure the safe operation of vertiports:

- Add a clause in Georgia Code Title 32-9-8 specifying that private-use airports that conduct 14 C.F.R. Part 121 and/or 135 operations shall meet the definition of airport, thus distinguishing between these facilities and private-use facilities that do not solicit the public.
- Stipulate in Georgia Rule 672-9 that any landing facility used by 14 C.F.R. Part 121 and/or 135 operations would be subject to licensing and inspection.
- Should the tempo and volume of operation rise to the level predicted in a mature state of AAM, evaluate whether the existing biennial inspection protocol for airports is appropriate and sufficient for vertiports.

Additional Best Practices

There are additional best practices related to AAM landing areas that can be modeled after studies from states such as Florida, Ohio, Texas, and Utah. Key takeaways from those efforts as they relate to AAM landing area safety are outlined below.

- Ensure any legislation related to AAM does not conflict with federal law or FAA authority.
- Provide consistency in landing area standards across the state to avoid a patchwork of differing regulations by municipality.
- Integrate vertiports and AAM infrastructure into existing statewide transportation planning, better defining the role and needs of the AAM ecosystem within the state and how they interact with existing transportation assets.
- Organize cross-department coordination between all relevant state departments to raise awareness for and literacy about AAM at the state government level and to ensure all state stakeholders are consulted. This dialogue should include conversations around fire safety and emergency preparedness for AAM landing facilities.

- Coordinate with and provide technical resources from the state to raise awareness for and literacy about AAM at the local government level. This should include dialogue about AAM landing area zoning, fire safety, and emergency preparedness for landing facilities.

5. Advancing the AAM Industry in Georgia

Today, air taxis, urban air mobility, distributed electrical propulsion, electric aircraft, and vertical takeoff and landing are all emerging topics of innovation in the aviation industry. Technological innovation promises to change the way we think about flight. AAM aircraft designers and leaders in this emerging sector of aviation are predicting improved aircraft and new markets that will bring great economic benefit to areas that adopt these modern technologies.

In November 2022, Georgia successfully landed a highly sought-after economic development prospect in the AAM industry. Archer Aviation, a leading eVTOL manufacturer, announced that they have selected Covington, Georgia for their high-capacity production facility (Archer Aviation, 2022). The initial phase of development will include a 350,000-square-foot manufacturing facility capable of producing up to 650 aircraft per year. Archer intends to invest $118 million in the site during the next 10 years, and the facility is expected to create more than 1,000 jobs in the long term.

Georgia economic development initiatives supported the deal through various incentives, including land conveyance, tax incentives, and a Georgia Regional Economic Business Assistance (REBA) grant. Additionally, Georgia plans to use its nationally recognized "Quick Start" workforce training program to meet human resource needs. Phase 1 construction is expected to occur during the first half of 2024, with production expected to begin in the second half of the year.

Archer Aviation is one of the hundreds of designers and original equipment manufacturers seeking to be first to market with an eVTOL aircraft. While not all companies will be successful, there are numerous viable designs that have a reasonable probability of success and that can be built and operated in the state of Georgia.

The AAM industry can be divided into three major sectors that could benefit the state economically:

1. Design and testing.
2. Aircraft manufacturing.
3. Passenger and cargo service providers/operators.

It should be noted that several business lines will form as suppliers and service providers to support the three sectors. Many of Georgia's strategic economic development strengths apply to all sectors.

This chapter will first highlight how statewide efforts in Georgia demonstrate its ability to support AAM aircraft design and testing, manufacturing, and operation in the state.

5.1 Design and Testing

Georgia is currently a leader in two key fields that have transferability to the design, testing, and manufacturing of eVTOL aircraft: electrical infrastructure and a thriving aerospace industry. These two strategic strengths are advantageous in attracting and sustaining an AAM industry in the state.

Electrical Infrastructure

Recent advancements in air mobility all focus on electrical propulsion. eVTOL aircraft will be powered by electric motors and these motors will need sufficient electric infrastructure to operate. Georgia is currently positioning itself as a hub for electric vehicles, batteries, and other support operations for the electric transportation industry, which could attract the AAM industry to the state. According to *Select Georgia*, the community and economic development wing of Georgia Power, more than 28,000 jobs were created by electric vehicle companies in the state between 2018 and 2023, and more than $23 billion in capital investment was generated (Select Georgia, 2023). This could be mirrored for AAM.

In March 2023, Georgia Power partnered with BETA Technologies and the Augusta Regional Airport to install an electric charging station for aircraft (Georgia Power, Georgia Power and BETA Technologies celebrate new charging infrastructure at Augusta Airport, March 24, 2023). The company also installed three charging stations for ground vehicles in the general aviation parking lot. This was BETA's 10th charging station in their network (Beta Installs First Electric Aircraft Recharging Station in the Southeast U.S., 2023). They currently have 55 additional sites under permitting or construction and have plans to build a total of 150 by 2025 (Beta Technologies, 2023). The installation of this network will enable longer-distance trips.

BETA Technologies recently completed such a trip from New York to Kentucky as they repositioned one of BETA's aircraft at UPS's Worldport facility (Cowan, 2022). UPS's subsidiary Flight Forward is expecting the first 10 BETA aircraft deliveries in 2024, where they expect to "benefit healthcare providers, thousands of small and medium-sized businesses, and other companies in smaller communities. With a 250-mile range and cruising speed of up to 170 miles per hour, UPS will be able to plan a series of short routes, or one long route, on a single charge to meet customers' needs" (UPS, 2021).

It should also be noted that the charging station in Augusta was made possible due to a Georgia Power program designed to ease the financial burden of installing and maintaining charging station infrastructure. Georgia Power's Make Ready Program "removes the biggest financial hurdle of installing electric chargers at your location by installing, owning, and maintaining the electrical infrastructure behind your meter up to the charger" (Georgia Power, 2023). BETA's network calls for four more charging station locations in Georgia (Beta Technologies, 2023).

Georgia has attracted, and continues to attract, electric transportation and infrastructure companies. In 2021, Georgia-based Energy Assurance LLC—a provider of cell and battery testing for performance, regulatory compliance, and failure analysis—acquired a 20,000-square-foot laboratory that will allow the company to expand into cell testing for the electric automotive and energy storage industries (Energy Assurance, 2021). Combined with their existing lab in Metro Atlanta, Energy Assurance (and by extension, Georgia) will have the largest independent battery-testing lab in North America (Energy Assurance, 2021).

There are additional key statewide initiatives in Georgia that support electric infrastructure and can be applied to attract the AAM industry. These initiatives are outlined below.

Electric Mobility and Innovation Alliance

The Georgia Electric Mobility and Innovation Alliance (EMIA) is a statewide initiative between government, industries, electric utilities, and nonprofits. (Georgia Department of Transportation, 2021). Led by the Georgia Department of Economic Development, the initiative is focused on growing the state's electric mobility ecosystem and strengthening Georgia's position in electrification-related manufacturing and innovation. This effort should be leveraged for AAM.

In 2021, EMIA released a report outlining e-mobility opportunities for Georgia (Georgia Department of Transportation, 2021). The report cites several factors for why Georgia is an attractive market for electric mobility projects, including Georgia's robust infrastructure, renewable energy production, and the availability and quality of talent in the workforce. The report identifies existing assets that can be built upon to continue Georgia's leadership in the industry.

Among these assets are:

- Active support of e-mobility from the Governor's Office, legislative leaders, local leadership, and key state agencies.
- The state's experience and success in building industry sectors, such as film, cybersecurity, logistics, and advanced manufacturing industries.
- Autonomous vehicle research already taking place in many parts of the state, including in the cities of Chamblee, Woodstock, and Peachtree Corners as well as in Gwinnett County.
- The rapidly expanding Southeast Automotive Alley, which Georgia is in the center of and which is home to 30 assembly plants located within 500 miles. Georgia also has an expansive network of automotive suppliers that support these plants.
- A reliable electric grid and low energy rates, which may incentivize in-state fleet owners to consider electrification and out-of-state fleet owners to consider Georgia as a potential electric fleet location.

The combination of pro-business state government leadership, research and workforce development, and an expanding network of electrical infrastructure positions Georgia as a leader in electric mobility. This leadership and proven success are key factors in marketing Georgia to AAM companies. *AAM should be included as a mode of transportation in the EMIA, bringing it to the forefront of their electrical initiatives.*

Electric Highway Coalition

The Electric Highway Coalition is a group of energy companies and includes Southern Company, Georgia Power's parent company. The coalition is collaborating on a network of fast chargers for electric vehicles in the Midwest, East Coast, and Southern regions of the United States to provide drivers in these regions with convenient charging options for electric vehicles. This coalition could also influence AAM companies to locate in Georgia if airports were included in its strategy. A state with electric aviation in its energy plans will appeal to AAM companies by showing state-level commitment to the electric infrastructure.

University Research and Engagement

Four universities in Georgia have established programs that further electric infrastructure in the State, as noted by Select Georgia's University Research and Engagement documentation (Select Georgia University Research & Engagement, 2023):

- The University of Georgia's College of Engineering is assessing the opportunities and challenges associated with advanced electric energy technology and smart infrastructure. The Carl Vinson Institute of Government at the University uses its statewide network to understand how electric vehicle technology impacts communities and enhances the competitiveness of Georgia's economy.
- The Georgia Institute of Technology's Strategic Energy Institute is developing technologies that are enabling lower cost, cleaner generation, and storage and distribution of energy. The Manufacturing Institute at this university is partnering with GE and Ford Motor Company to add efficiencies to electric driving and charging performance.
- The Georgia Institute of Technology's Center for Urban and Regional Mobility works directly to advance AAM in Georgia. The Center leads research and education related to urban air mobility and new forms of regional aviation. The Center develops and curates research products including simulation models, demand forecasts, technology test laboratories, and flight demonstrator testbeds. Recently, a NASA-funded study by the Center indicated significant demand for shorter-

distance flights, served by 9-30 electric jets. The study identified demand for over 4,200 origin and destination markets, connecting 980 different airports across the United States.

- Georgia Southern University participates in the "Engaging Educators in Renewable Energy" (ENERGY) programs. ENERGY is a National Science Foundation grant providing teachers and faculty workforce with professional development on renewable energy content and teaching strategies.
- Augusta Technical College offers a hybrid/electric vehicle repair technician certificate.

These institutions are pivotal to furthering the development of electric infrastructure in Georgia, both through research and development as well as through workforce development. Access to the talent at these universities offers significant value to AAM companies looking to locate in the state.

Georgia Electric Vehicle Infrastructure Deployment Plan

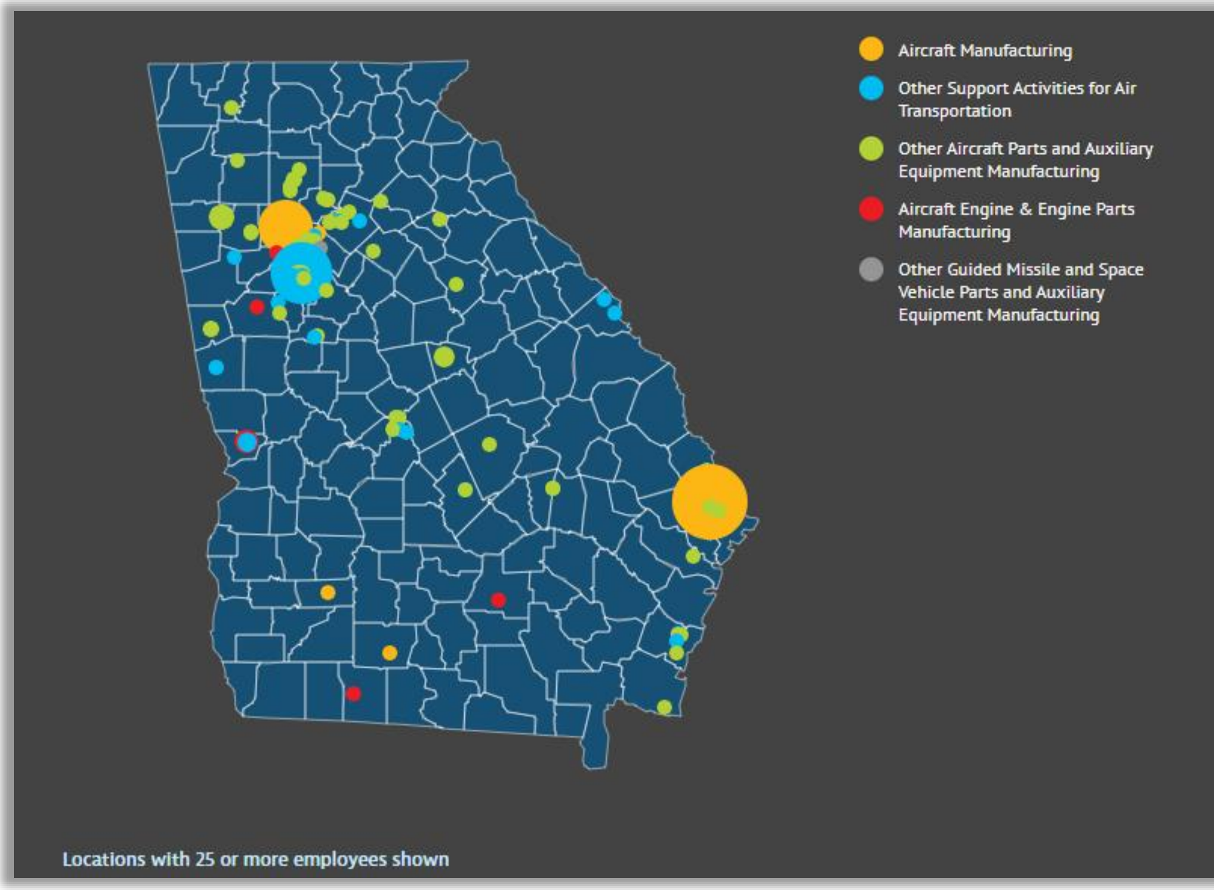
The 2021 Infrastructure Investment and Jobs ACT (IIJA) provided for the creation of the National Electric Vehicle Infrastructure (NEVI) Formula Program. The program goal is to deploy a national network of electric vehicle charging stations. As part of that, GDOT developed an EV Infrastructure Deployment Plan to take advantage of the NEVI program's funds to build electric charging stations across the state (Georgia's Electric Vehicle Infrastructure Deployment, 2022). These charging stations apply to charging for electric cars, not eVTOL aircraft, but the development of this plan echoes Georgia's larger commitment to electrify transportation in the state. A similar program could be leveraged to develop a network of charging stations for eVTOLs in locations across Georgia.

5.2 Aircraft Manufacturing

Aerospace Industry

Georgia's leadership in aerospace manufacturing is well established, boasting a workforce of more than 200,000 individuals involved in sectors such as aircraft manufacturing, aircraft engine and engine parts manufacturing, and aircraft parts and auxiliary equipment manufacturing. Among states in the Southeast, Georgia ranks first in exports of aircraft and aircraft engines and parts. There are numerous large aerospace manufacturers and suppliers in Georgia, including Gulfstream Aerospace Corp (9,700 workers), Delta TechOps Division (6,640 workers), and Lockheed Martin (5,000 workers), as well as several other aerospace-related companies (Select Georgia, 2023). **Figure 5-1** shows the location and distribution of aerospace businesses with more than 25 employees across the state.

Figure 5-1: Aerospace Business Across Georgia



Source: (Select Georgia, 2023)

Georgia's aerospace industry continues to grow. During the past five years, new locations and announced expansions have continued. **Table 5-1** lists recent aerospace industry expansions and new sites in Georgia.

Table 5-1: Aerospace Expansions or New Sites in Georgia 2017-2022

Company	Jobs Created/ Retained	County	Year
AeroDynamic Aviation	30	Effingham	2021
Anduril Industries	180	Fulton	2022
Aspen Angels	250	Bulloch	2022
Denkai America	250	Richmond	2022
Embraer Engineering & Technology	100	Bibb	2019
Gulfstream Aerospace	200	Chatham	2018
Mallaghan	30	Coweta	2018
Meggitt Polymers & Composites	211	Polk	2017
Pratt & Whitney	500	Muscogee	2017
Rolls Royce	20	Chatham	2021

Company	Jobs Created/ Retained	County	Year
TECT Corp.	75	Thomas	2017

Source: (Select Georgia, 2023)

Georgia's airports also support significant aerospace activity. Across the state's airports, there were 581 business tenants, 24 percent of which were in aircraft maintenance/manufacturing. The 2020 Statewide Airport Economic Impact Study pinned the annual economic impact of Georgia's airports (including Hartsfield-Jackson Atlanta International) at approximately $73.3 billion (Georgia Department of Transportation, 2020).

Georgia Center of Innovation

The Georgia Center of Innovation is a strategic arm of the Georgia Department of Economic Development (Georgia Institute of Technology, 2023). The Center's aerospace team connects industry businesses to the resources they need to succeed, from university researchers to business organizations and others. The Center helps organizations with aerospace manufacturing, maintenance and repair, research, and education. Companies looking to locate in Georgia can contact the Center and be connected to resources and expertise in aerospace.

Aerospace Research and Education

Georgia has numerous universities with aerospace programs, including the following four-year schools: Georgia Institute of Technology, University of Georgia, Kennesaw State University, and Georgia Southern University. The state is also home to six technical colleges: Georgia Northwestern Technical College, Savannah Technical College, South Georgia Technical College, Atlanta Technical College, Augusta Technical College, and Central Georgia Technical College. These colleges and universities produce significant amounts of talent ranging from aerospace engineering to aircraft maintenance and operations. Coordination should occur with these schools to develop programs related to AAM, including specific electric aircraft manufacturing and maintenance training, to ensure a sufficient workforce that supports AAM in the state.

5.3 Aircraft Operators

Sections 5.1 and 5.2 outlined the key initiatives in electric infrastructure that Georgia is undertaking and how they can support attracting AAM companies for designing, testing, and manufacturing in the state. These same electric initiatives can also support attracting AAM operators to Georgia. The predominant aircraft in AAM are eVTOL, which need electricity to operate. For high-volume or high-tempo eVTOL traffic to exist anywhere, a sufficient network of recharging facilities will be needed, as they are for electric surface vehicles. This will be a vital requirement for eVTOL service providers to be successful in the state. If the infrastructure for electric aircraft is already in place, it is more likely that existing aviation users will adopt this new technology. This means that developing and implementing a network strategy to outfit airports with electric aircraft chargers in Georgia can have a positive impact on the adoption rate of electric aircraft among existing infrastructure users. It will allow the state's airports to readily act as the starting or ending point of an eVTOL air taxi trip without the need for any vertiports to be built.

Furthermore, having an established charging network in place can also attract new users who are interested in electric aviation but hesitant due to the lack of infrastructure. By investing in electric aircraft infrastructure, Georgia airports can position themselves as leaders in sustainable aviation and attract a wider range of users.

Because eVTOL use will be market-driven, certain demographics will play a role in their adoption. A passenger service using eVTOL aircraft will require an abundant supply of people in a population-dense area who need to travel. Georgia is currently the eighth most populous state in the U.S. and is undergoing a noteworthy surge in both its population and economy—it has been among the top five population gainers in the past decade (America Counts Staff, 2021). Additionally, with major metropolitan areas like Atlanta, the state has a sizable number of daily commuters that could attract an urban air mobility operation, moving commuters off of the interstates.

In addition to its large population, Georgia is attractive because of its geography. It is a warm, low-altitude state, which is beneficial for early eVTOL aircraft that are limited by battery capacity and performance. In cold weather, lithium-ion batteries lose capacity at a higher rate than at warmer temperatures, and the lower air density at high altitudes means that aircraft must exert more energy to stay in the air.

5.4 Conclusions

Georgia is well positioned to strengthen its already robust aerospace industry by continuing to attract companies in the advanced air mobility sector. The large aerospace industry presence and the existing AAM presence through Archer and BETA Technologies place the state in an advantageous position with respect to other states. Partnerships and programs to assist with infrastructure development—along with already proven economic development practices—have already resulted in the state being home to an eVTOL manufacturing facility and one of the first electric charging stations to be installed at an airport. However, more can be done.

Previous work in planning a statewide vehicle charging network across the state can be leveraged for airports. A great example is the installation of BETA's charging system in Augusta, where three vehicle chargers were also installed in the auto parking lot. Consideration can be given to airports and aircraft charging stations when conducting vehicle installations across the state.

Existing universities and community and technical colleges can provide the much-needed workforce to attract and grow the AAM industry. Some programs currently exist, while others can be expanded or developed to meet not only Georgia's needs, but the rest of the country's as well. As noted above, a well-qualified and trained workforce pipeline is key to engaging and retaining any industry, and AAM companies are no different.

The elements of success are already present in the state; Archer and BETA are proof of this. The state will benefit from more coordination among AAM ecosystem stakeholders, and leveraging existing resources and related programs to reorient them toward AAM can help drive success. Georgia's favorable weather, growing population, associated traffic congestion, and the mobility needs of residents and visitors to Atlanta's Metropolitan areas will make the state an attractive market for operators.

Takeaways: Design and Testing

To draw AAM companies to the state, Georgia should focus on its strengths and the distinct advantages it has in its robust electrical infrastructure, strong colleges and universities, and thriving aerospace industry. AAM companies will be able to position themselves in proximity to top-tier leaders in these fields, all while the state's numerous universities supply a steady stream of skilled professionals to bolster their operations.

Many of the tools that Georgia can use to market the state to AAM companies are the same used to attract other industries. This includes a suite of state-offered economic development services, including tax incentives, site-selection assistance, and workforce training. Additionally, Georgia can take the following steps to increase marketability to AAM companies for design, testing, and manufacturing:

Electric Infrastructure

- More fully integrate the needs of eVTOL aircraft and associated infrastructure into the Electric Mobility and Innovation Alliance Report.
- Form a coalition similar to the Electric Highway Coalition to establish a network of charging stations for eVTOLs and other electric aircraft at airports across the state.
- Build upon GDOT's NEVI plan and develop an EV Infrastructure Deployment Plan that considers eVTOL charging stations and potential funding sources for those stations.
- Promote existing workforce development programs such as Georgia Power's Make Ready Program.
- Coordinate with universities and community/technical colleges to understand electric infrastructure and technology programs to best determine if programs can support AAM and where program development opportunities may exist.
- Co-locate dual-use charging stations that can support both automobile and aircraft charging.

Takeaways: Aircraft Manufacturing

Aerospace Industry

- Survey existing aerospace industry leaders in Georgia to understand their roles within AAM and any needs associated with that role.
- Survey Georgia airports to determine if any airport business tenants can support AAM testing or manufacturing.
- Coordinate with existing economic development leaders to understand the tools and incentives Georgia offers and whether any modifications are needed to attract AAM companies.
- Coordinate with universities to compile existing aerospace programs and identify opportunities for those programs to support AAM workforce development.

Takeaways: Aircraft Operators

Georgia should apply many of the same initiatives it has undertaken to support the design, testing, and manufacturing of AAM aircraft to attract AAM operators. Key takeaways include:

- Build out a network of supporting infrastructure for AAM, especially electric charging stations for eVTOL aircraft.
- Promote Georgia's climate, geography, and population density as favorable for AAM operations.
- Promote Georgia's population and economic growth as opportunities for a strong and growing consumer base.
- Apply the CONOPS produced as part of this AAM Study to better conceptualize and advertise the reality of AAM operations in the state.

6. Economic Projections for Advanced Air Mobility in Georgia

Aviation in Georgia is a large revenue generator, and the economic impacts and benefits to the state are enormous. These include economic activity provided by airlines, aerospace companies, airports, and the businesses that operate from them. New and emerging technologies in aviation will add to these benefits as AAM evolves and matures. This chapter characterizes the economic potential of the AAM industry and provides some understanding of what Georgia could gain from attracting and implementing this new form of transportation during the next 20 years.

6.1 What are Economic Impacts and Benefits?

Traditional economic impact modeling is a common practice to evaluate the monetary benefits brought by a new company or service in a particular geographic area or state. Economic impacts are derived from job creation and subsequent spending by the company and its employees. Benefits—even temporary construction jobs—are also derived from capital improvements. New businesses take in new revenue and then pay their employees and vendors, who subsequently spend that money in the larger economy.

The aviation industry—specifically airports, and soon vertiports—generates passenger activity. Many of these passengers are visitors to the region and will spend money at hotels and restaurants. This visitor spending also creates an economic impact, as the visitors' dollars are spread across the travel, tourism, and hospitality industries. The establishments where this money is spent, in turn, spend the money to pay employees and suppliers, resulting in a multiplier effect as the initial spending ripples through the economy.

Economic impacts are communicated in simplified terms of employment (jobs created), total payroll, and total economic output. The total economic impact is a measure of the total value of goods and services. Additional impacts are measured from any capital improvement and associated visitor spending. Typical economic modeling outputs also incorporate the amount of state and local taxes generated from the business activities.

6.2 What are the Benefits to Georgia?

In addition to the more common economic impacts often associated with airports and aviation, a wide range of additional benefits can potentially come to the state from the AAM industry. Additional economic benefits can come from the development of AAM-specific infrastructure that includes vertiports and their associated charging stations. More benefits can be expected as these aircraft become operational.

First among these benefits are job creation and workforce development. AAM manufacturers and operators will require a workforce skilled in engineering, manufacturing, maintenance, operations, and associated services (e.g., retail, hospitality, and car rental facilities). For those areas requiring new or additional workers, community and technical colleges as well as four-year institutions can provide job training and workforce pipeline development to ensure a steady and reliable labor force to support the industry.

When the AAM industry becomes established, certain ancillary benefits such as sustainability and safety may be realized. Electric aircraft operations can drive environmental benefits through reduced greenhouse gas emissions and improved air quality. The benefits of AAM operations depend on their frequency and location. However, these emission-free flights will replace some amount of highway travel. In turn, as these operations become more widespread, automobile accidents could be reduced, travel times improved, and levels of connectivity increased.

While individual users of AAM will directly see these benefits, surface transportation users will also see improvements in AAM corridors or markets where meaningful traffic volumes are removed from the highway system. Ultimately, at scale, AAM will translate into enhancements in safety and sustainability, reducing both congestion and mobile source emissions.

AAM also provides opportunities for the tourism industry. Although not one of the most-discussed use cases, AAM can provide transportation to hard-to-reach locations or rapid air transit for time-constrained travelers wanting to bypass highway trips. This expanded access could increase existing and generate new tourism, thus bringing an added economic benefit to those markets.

6.3 Statewide Aviation/Aerospace Industry Economic Impacts

Georgia is home to several large players in aviation. It is the headquarters for both Delta Airlines, one of the largest air carriers in the world, and United Parcel Service (UPS), the third largest air cargo carrier in the world. Delta Airlines had 2022 annual revenues of more than $50 billion and employed 90,000 workers (Clarke, 2021) while UPS's 2022 annual revenues were $100.3 billion with more than 500,000 employees (United Parcel Service, 2022). Several large aerospace companies also have a significant presence in the state: Airbus, Gulfstream, Lockheed Martin, Pratt & Whitney, Raytheon, and Thrush.

Aerospace products are the state's top export with a value of $9.2 billion (Georgia USA). Airports also provide significant economic benefits to the state. In 2020, Georgia's 103 airports generated a total economic impact of $73.3 billion (Georgia Department of Transportation, 2020). This includes an economic impact of $66.8 billion from Hartsfield-Jackson Atlanta International, $5 billion from the state's other eight commercial service airports, and $1.9 billion from the 94 general aviation airports. Military airfields add an additional annual impact of $13.2 billion. Airports alone account for more than 83,500 jobs, $1.4 billion in state and local tax revenues, and 15 percent of Georgia's gross domestic product (Georgia Department of Transportation, 2020)

In addition, Georgia has six airports with daily scheduled all-cargo service and seven airports with commercial airline service with belly cargo. An additional 58 airports in the state system have supported air cargo activity through ad-hoc or on-demand air cargo operations. Collectively, the value of commodities that enter or leave the state by air is $30 billion (Georgia Department of Transportation, Air Cargo Study, 2021)

Much like the other elements of the aviation and aerospace industry, the advent of the AAM industry in Georgia will bring economic and other benefits to the state. It will bring investment and jobs that will provide an influx of capital and spending that will flow through the larger economy.

6.4 Current Investment in AAM

The AAM industry has seen significant investment from a variety of sources. Some aircraft are being developed by large, publicly traded companies, but the investment in AAM is not widely known. The development of and investment in these new aircraft has come from both traditional aircraft manufacturers and new companies devoted solely to their development. Additional investment has come from airlines, automobile manufacturers, and technology companies, among others. **Table 6-1** shows the top 14 companies, ranked by investment of over $100 million each, resulting in a net amount of nearly $8 billion.

Table 6-1: AAM Companies by Funding

Company	Funding ($Million)
Joby Aviation (NYSE: JOBY)	$1,904.60
Lilium (NASDAQ: LILM)	$1,057.00
Archer (NYSE: ACHR)	$856.30
BETA Technologies	$796.00

Company	Funding ($Million)
Wisk	$775.00
Volocopter	$761.00
Eve Holding (NYSE: EVEX)	$377.40
Vertical Aerospace (NYSE: EVTL)	$347.80
AutoFlight	$200.00
Eviation	$200.00
Overair	$170.00
Ehang (NASDAQ: EH)	$142.00
Electra	$134.00
SkyDrive	$120.50
Total (Top 14)	**$7,841.60**

Source: (AAM Reality Index, 2023)

In addition, there are also corporate-backed AAM entities where the funding level is unknown. They are composed of traditional aerospace companies and automobile manufacturers:

- Pipistrel (Textron)
- Airbus
- Supernal (Hyundai)
- Honda Motor Company
- eAviation (Textron)
- Volkswagen

While several large automobile companies are involved in developing their own aircraft, many ventures are investor-driven or partnerships to source development to third parties. These joint efforts are addressed in the next section.

Automobile Company Partnerships

While the interest of automobile manufacturers in developing eVTOLs may at first seem out of place, there are significant synergies at play. Hyundai, Honda, and Volkswagen have all been at work developing eVTOL aircraft (SMG Consulting, 2023). Several other automobile companies have invested in and partnered with eVTOL manufacturers, as shown in **Table 6-2.**

Table 6-2: eVTOL OEM and Automobile Partnerships

eVTOL OEM	Automobile Manufacturer Partner
Joby Aviation	Toyota
Archer Aviation	Stellantis (Chrysler, Dodge)
Lilium	Denso (automotive components, Japan)
Volocopter	Daimler (Mercedes-Benz)

eVTOL OEM	Automobile Manufacturer Partner
Eve Air Mobility	Porsche

Source: (Patterson, 2022).

The primary reasons for these strategic and financial partnerships and relationships are twofold. First, automobile companies have extensive experience in large-scale manufacturing. Second, the proliferation of electric cars has provided automobile companies with insight into manufacturing and maintaining electric vehicles. These assets are of inevitable interest to eVTOL manufacturers, whose focus to date has largely been the design and testing of vehicle prototypes as they work through the aircraft certification process.

Airline Investment

Much like automobile companies, airlines have also been investing and partnering in eVTOL technology to enhance their transportation capacity and capabilities. Of note are investments in Joby from Delta Airlines (initially $60 million, with the potential to reach $200 million) and JetBlue Ventures (the amount of which is unspecified) (Russell, 2022). United Airlines has partnered with Archer and ordered 200 eVTOLs (Ahlgren, 2023). They have also made a $15 million investment in Eve Air Mobility and a conditional agreement to purchase 200 of Eve's aircraft (United Airlines backs Eve Air Mobility with $15M investment, 2022).

American Airlines has likewise partnered with AAM companies, with an initial investment in Vertical Aerospace in 2021 of $25 million. The agreement established an initial order of 50 eVTOL aircraft, with the potential for an additional order of 200. Vertical Aerospace also has provisional orders with AirAsia (100 aircraft), Virgin Atlantic (150 aircraft), and Brazilian low-cost carrier GOL (250 aircraft) (Ahlgren, 2023).

Other investments and partnerships of note include Bristow Group's option to purchase 50 Lilium Jets and the provision to provide maintenance for Lilium's Florida network (Lilium, 2022). Lilium's partnerships also number 40 orders for AAP Aviation (a Norwegian crew management/operational company), 100 for Saudi Airlines, and 200 for Brazilian Azul Airlines. While Airbus has partnerships with ITA Airways and the Munich Airport (Ahlgren, 2023), the Boeing Company invested $450 million in Wisk Aero (Wisk Aero, 2022), and Embraer (EVE) has established partnerships with Skywest, Kanya Airways, Republic Airways, and some other smaller airlines (Ahlgren, 2023).

UPS and FedEx have both developed partnerships with AAM companies for cargo delivery. UPS Flight Forward is working with BETA in testing new vehicle delivery options, specifically the Alia-250 eVTOL, and has placed an order for 10 aircraft with an option to buy up to 150 (Warwick, 2022). FedEx has been working with Elroy Air in testing its autonomous cargo drone, which can carry up to 500 pounds (Brinkmann, 2022).

6.5 AAM Intersection with Georgia

With a population of 10.9 million people, Georgia is the eighth largest state in the country (U.S. Census Bureau, State Population Estimates, 2022) and the 15th most dense in residents per square mile (Statista Research Department, 2022). Most of the state's population is in the Atlanta-Sandy Springs-Roswell Metropolitan Statistical Area (MSA), where the 2021 population was 6,144,050 (Federal Reserve Economic Data, 2022). It is currently the eighth-largest MSA in the country (U.S. Census Bureau, 2022). Concentration of the state's population in the Atlanta metro area contributes to it being the 12th most congested region in the country. The annual delay per commuter was most recently recorded as 37 hours per year. This data, which is from 2020, is the most recent available and captures activity during the pandemic. Annual delay was even higher in 2019 (78 hours per commuter) before the trend in remote work materialized (Texas A&M Transportation Institute).

As the country continues to emerge from the pandemic, measurements of congestion, commute times, and delay are expected to return to more typical ranges. All of this, in conjunction with the anticipated benefits noted above, provides an opportunity for Advanced Air Mobility to be developed, implemented, and integrated into the larger transportation system. The state's role in establishing an AAM Working Group and the significant investments in AAM made by Georgia-based companies further confirm this.

eVTOL Operators/Manufacturers

This section highlights those specific investments and partnerships with a direct connection to Georgia. As noted earlier, Archer has made a notable investment in Covington, Georgia where it began construction of its eVTOL manufacturing facility at the Covington Municipal Airport in March 2023. The $118-million facility, located on 96 acres, is expected to include a 350,000-square-foot factory capable of manufacturing 650 aircraft per year (Spigolon, March 9, 2023).

A more recent development is the partnership between BETA, Georgia Power, and the Augusta Regional Airport. On March 22, 2023, the airport held an event to mark the installation of its first electric charging station. The system supports fast charging (up to 350kW) and is BETA's first in Georgia and the entire southeast United States (Georgia Power, March 24, 2023). BETA is undertaking a nationwide charging network and plans for four more stations in Georgia, as noted in **Chapter 3** (BETA Technologies, 2023).

Universities

Georgia's universities play a key role in the state's economic future, and those with aviation-related programs will help drive the AAM industry in the state. Whether it's innovative research or the development of a prepared workforce pipeline, the roles of universities and colleges in the state are critical.

Georgia Institute of Technology in Atlanta has been deeply engaged in advanced air mobility research. Through its Center for Urban and Regional Air Mobility (CURAM), faculty and students engage in interdisciplinary research that cuts across several academic disciplines, including multiple colleges and research centers across the campus (Georgia Department of Transportation, Statewide Airport Economic Impact Study, 2020). Faculty involved in this work are from disciplines such as aerospace, biological, civil, chemical, computer, electrical engineering, mechanical engineering, urban and regional planning, computer science, and public policy, among others.

CURAM's aim is to establish the Atlanta metro area as a living laboratory for AAM integration. Together with faculty and researchers in The Guggenheim School of Aerospace Engineering and elsewhere across campus, CURAM's areas of expertise include novel air mobility applications, operations research, urban and regional planning, demand modeling, sustainability, infrastructure, user and community perception, noise, virtual and augmented reality, autonomy, aircraft design, actuators and mechanisms, electric and hybrid propulsion systems, flight control, aerodynamics, structural mechanics and design, systems engineering/test/evaluation, and cybersecurity (Georgia Department of Transportation, Statewide Airport Economic Impact Study, 2020).

Additional centers at Georgia Tech involved in related research include the Center for Advanced Machine Mobility Aerial Robotics and the Experimental Autonomy Lab (AREAL), the Vertical Lift Research Center of Excellence (VLRCOE), the Interactive Media Technology Center (ITMC), and the Multiphysics Mechanics of Materials Lab (M3Lab).

Middle Georgia State University is home to Georgia's only four-year public aviation program (Middle Georgia State University, 2023). While the main campus is in Macon, the aviation program is housed in Eastman at the Heart of Georgia Regional Airport, approximately 60 miles to the southeast. The School of Aviation offers a comprehensive array of degrees and certificates through its two departments, Aviation Science and Management and Aviation Maintenance and Structural Technology. Bachelor's degree offerings include

Aviation Science and Management and Technical Management. The Aviation Science and Management Department has two tracks, management and flight, with the school offering comprehensive flight training options. Applied associate degrees can be pursued in Air Traffic Management, Aircraft Structural Technology, and Aviation Maintenance Technology. The school also offers four certificate programs in airline management, airport management, aviation safety, and technical operations management (Middle Georgia State University, 2023). The university's Institute for Applied Aerospace Research collaborates with the National Aeronautics and Space Administration (NASA) on various research projects.

Clayton State University is in Morrow, Georgia, approximately 15 miles south of Atlanta. The university offers a minor in Aviation Administration (Clayton State University, 2023). The 18-credit hour program requires courses in fleet planning and scheduling, leadership in aviation, aviation safety, airport operations, aviation labor relations, and homeland security. The program also offers students studying in other disciplines an opportunity to learn from aviation professionals and understand the key issues in the industry today.

Embry-Riddle Aeronautical University (Worldwide) has a campus in Atlanta, where they offer associate, bachelor's, and master's degrees in aviation disciplines. They also offer some certificate programs. The university has been involved in various aspects of eVTOL research at its flagship campus in Daytona Beach, Florida.

6.6 Potential Economic Impact

Fully determining the economic impact of AAM in Georgia is a large undertaking and is outside the scope of this study. However, it is possible to ascertain the potential economic impact of AAM in the state by looking at studies performed at the national level and for some states. Any examination of previous work should consider fluctuations in market conditions, and studies performed before or during the COVID-19 pandemic may face unique conditions and assumptions.

Studies at the national level also provide ranges with a base number along with upside and downside values. Each of these ranges accommodates a set of constraints and assumptions about AAM, its evolution, its operating characteristics, and its integration into our aviation and transportation systems. The team reviewed four national-level studies and two state-specific studies to better understand AAM's potential economic impact in Georgia.

National AAM Economic Impact Studies

One of the earliest market studies of UAM was funded by NASA and completed by Booz Allen Hamilton in 2018. The analysis included detailed cost assumptions and trip estimates based on a variety of factors. The study covered 10 urban areas selected by the research team. While no time frame is given, the market analysis presumes current cost and demand while making assumptions about other factors, including aircraft operational characteristics.

For the air taxi and airport shuttle markets, the research showed potential for 11 million daily trips and an unconstrained market value of $500 billion across the United States (Booz Allen Hamilton, 2018). When factoring in certain constraints, daily trips and market value decrease, and considering willingness to pay reduces the market value to $400 billion. Other constraints, such as lack of infrastructure and weather in certain markets, can drop the value significantly.

An analysis performed by Deloitte and published in January 2021 placed the value of the AAM market at $17 billion in 2025 and $115 billion in 2035 (Deloitte, 2021). This includes the passenger and cargo markets, which Deloitte sees as being evenly split in 2035. Deloitte also expects the AAM workforce to be 280,000 in 2035 with 234,000 of those in the U.S. market. These jobs are expected to generate a payroll of approximately $30 billion, $20 billion in exports, and tax revenues of $8 billion (of which $6 billion are federal and $2 billion are local) (Deloitte, 2021).

In May 2021, Morgan Stanley Research published its own economic analysis of the UAM market (Morgan Stanley Research, May 6, 2021). **Table 6-3** below shows the range of their market value estimates through 2050. The total addressable market represents the available market or overall revenue opportunities.

Table 6-3: Total U.S. Addressable Market (Billions of Dollars)

Scenario/Year	2020	2025	2030	2035	2040	2045	2050
Base	$1	$2	$12	$66	$279	$1,081	$2,450
Bull	$1	$6	$86	$446	$1,228	$2,661	$5,134
Bear	$1	$1	$5	$24	$96	$336	$626

Source: (Morgan Stanley Research, May 6, 2021)

The estimates shown above include passenger and cargo markets and those associated with military and defense, focusing on the end market services. The same research shows a base global market value of more than $9 trillion in 2050.

A recently published report on urban air mobility by the Airport Cooperative Research Program provides some of the latest estimates of the market value of the industry. In *Urban Air Mobility: An Airport Perspective*, the research team developed a market assessment model after reviewing existing literature across industry and academia. The methodology calls for developing a baseline case along with an upside and downside estimate to accommodate various constraints and market conditions. The assessments focus on passenger service, cargo service, and emergency services. Market assessments are provided for various UAM industry elements. The authors note that the "overall economic impact of UAM remains to be quantified, and key milestones and metrics for tracking public accessibility and affordability also need to be defined (National Academies of Sciences, 2023)." However, the estimates provided are the most recent and comprehensive to date to better understand what the economic impacts may be.

Tables 5-4 through **5-8** show the baseline, upside, and downside market assessments for various sectors within the AAM market. These include OEM/suppliers, infrastructure developers, infrastructure operators, flight service providers, and maintenance/repair services and impacts are shown for each of the three markets.

Table 6-4: OEM and Supplier Market Assessment

Year	2025 ($M)			2035 ($M)		
Market/Assessment	**Downside**	**Baseline**	**Upside**	**Downside**	**Baseline**	**Upside**
Air Metro	55-60	110-120	275-300	1,130-1,160	17,600-7,700	24,800-25,000
Air Cargo	1,000-1010	1,900-2,000	3,950-4,050	1,100-1,120	2,100-2,200	4,100-4,200
Air Medevac	5-7	30-50	95-$100	40-42	125-135	500-510

Source: (National Academies of Sciences, 2023)

Table 6-5: Infrastructure Developer Market Assessment (Millions)

Year	2025 ($M)			2035 ($M)		
Market/Assessment	**Downside**	**Baseline**	**Upside**	**Downside**	**Baseline**	**Upside**
Air Metro	100-150	210-220	560-570	23,950-24,050	41,050-41,150	64,100-64,300
Air Cargo	13,900-14,100	24,000-26,000	50,000-53,000	51,000-54,000	101,300-101,500	227,900-228,100
Air Medevac	10	69	253	72	275	1,305

Source: (National Academies of Sciences, 2023)

Table 6-6: Infrastructure Operator Market Assessment (Millions)

Year	2025 ($M)			2035 ($M)		
Market/Assessment	**Downside**	**Baseline**	**Upside**	**Downside**	**Baseline**	**Upside**
Air Metro	7	14	35	1,650	2,680	3,970
Air Cargo	580	1,960	4,910	2,190	8,000	21,535
Air Medevac	5.9	33	98	41	30	508

Source: (National Academies of Sciences, 2023)

Table 6-7: Flight Service Provider Market Assessment (Millions)

Year	2025 ($M)			2035 ($M)		
Market/Assessment	**Downside**	**Baseline**	**Upside**	**Downside**	**Baseline**	**Upside**
Air Metro	54	110	270	12,730	20,620	30,600
Air Cargo	8,320	11,730	18,540	31,300	47,960	81,266
Air Medevac	8	$400	1,180	270	1,600	5,880

Source: (National Academies of Sciences, 2023)

Table 6-8: Maintenance, Repair, and Overhaul Market Assessment (Millions)

Year	2025 ($M)			2035 ($M)		
Market/Assessment	**Downside**	**Baseline**	**Upside**	**Downside**	**Baseline**	**Upside**
Air Metro	130	$500	750	3,500	4,140	4,770
Air Cargo	360	10	810	1,365	2,090	3,540
Air Medevac	1.2	17	51	12	70	256

Source: (National Academies of Sciences, 2023)

The model developed by the research team also provided estimates of the market assessment values for fleet management services and the physical security market that will exist due to passenger service. To determine a total market assessment value using the above sector assessments, **Table 6-9** shows the sum from the prior tables. In the cases where ranges are provided, for simplicity, the lower value was used for the downside scenario, the higher value was used for the upside scenario, and an average of the range was used for the baseline scenario.

Table 6-9: Total Market Assessment (Millions)

Year	2025 ($M)			2035 ($M)		
Market/Assessment	**Downside**	**Baseline**	**Upside**	**Downside**	**Baseline**	**Upside**
Air Metro	346	954	1,925	42,960	86,190	128,640
Air Cargo	24,160	41,150	81,310	86,955	161,600	338,641
Air Medevac	50	559	1,682	435	2,205	8,459
TOTAL	24,556	42,663	84,917	130,350	249,995	475,740

Source: (National Academies of Sciences, 2023)

The total market assessment for the industry sectors examined above, for the baseline scenario, is expected to be $42.6 billion in 2025 and grow to nearly $250 billion in 2035.

State Economic Impact Studies

While economic impact data is limited nationally, it is even more scarce on a state level. Three states have conducted some semblance of economic impact modeling for AAM: Ohio, Virginia, and Arkansas.

In June 2021, the Ohio Department of Transportation, Office of Statewide Planning and Research published a study entitled *Infrastructure to Support Advanced Autonomous Aircraft Technologies in Ohio*. The report included potential economic impact for AAM in the state. The total economic impact was estimated to be $13 billion during a 25-year period from 2021 to 2045 (Del Rosario, June 2021). Additional impacts included the creation of 15,000 new jobs and more than $2.5 billion in federal, state, and local taxes. On a more granular level, approximately $1 billion of this was attributed to ground infrastructure, $500 million to traffic management services, $9.2 billion to AAM operators, and $2.3 billion to aircraft.

The report also provides forecasted estimates of ridership, operator revenues, and capital expenditures for AAM-related facilities for the largest cities in Ohio. **Table 6-10** shows this data, which provides a good frame of reference for what other states and cities may expect.

Table 6-10: Market Value and Forecasted Demand by City (in thousands)

City	Projected Vertiports	Total Yearly Passengers (2040)	Total Passenger Operator Revenues	Total Ground Infrastructure CAPEX	Total Ground Infrastructure OPEX	Service Providers CAPEX	Service Providers OPEX	Total Service Provider Costs	Total Passenger Vehicle Costs
Akron	14	943.6	$799,099.1	$59,746.8	$135,540.7	$29,270.9	$33,609.7	$62,880.6	$254,828.1
Cincinnati	16	1,592.3	$1,770,277.4	$64,711.7	$148,228.4	$42,427.1	$53,798.5	$96,225.6	$306,772.1
Cleveland	16	1,565.8	$1,481,763.4	$64,7117	$148,228.4	$40,987.9	$52,298.2	$93,286.1	$306,772.1
Columbus	22	1,809.3	$1,932,905.2	$70,759.1	$159,988.0	$48,534.1	$60,191.3	$108,725.5	$375,132.1
Dayton	9	808.2	$591,180.8	$55,932.8	$128,872.6	$23,042.0	$32,701.9	$55,743.9	$206,782.3
Toledo	4	1,171.8	$489,655.5	$7,043.4	$16,766.7	$18,691.6	$29,116.7	$47,808.2	$218,253.8
Total	**81**	**7,891.1**	**$7,064,881.4**	**$322,905.5**	**$737,624.7**	**$202,953.5**	**$261,716.3**	**$464,669.8**	**$1,668,540.4**

Source: (Del Rosario, June 2021)

Total passengers for these six Ohio metro areas are expected to be nearly eight million in 2040, with passenger revenues of more than $7 billion annually. The other expenses are cumulative and would take place on a build-out schedule specific to each city.

In January 2023, the State of Virginia published an economic benefits report commissioned by the Virginia Innovation Partnership Corporation and the Office of the Secretary of Commerce and Trade. The report includes a 23-year forecast and estimates $16.4 billion in new business activity during that period (Georgia Electric Mobility and Innovation Alliance, 2021). This includes more than 17,000 jobs and $2.8 billion in newly generated tax revenues at the local, state, and federal levels. It also estimates that 66 million passengers will travel on an eVTOL in Virginia over the next 23 years. In the 2041–2045 timeframe, it is estimated that about 7.7 million passengers per year—or 21,000 passengers daily—will use AAM.

The Virginia study also includes estimates for revenues and expenditures of the AAM supply chain by four classification areas: ground infrastructure, traffic management systems, UAM operators, and vehicles. **Table 6-11** shows the total expenditures or revenues for these supply chains during the next 23 years. The 66 million passengers, along with cargo operations and medevac operations, are expected to drive total revenues of more than $8.6 billion from 2023 to 2045. Capital investment and operating expenses for ground infrastructure, vehicles, and traffic management services add nearly $8 billion to the total. These are shown in more detail below.

Table 6-11: AAM Revenues/Expenditures in Virginia, 2023-2045

		2023-2045	Total by Supply Chain
Demand (Passengers)		66,125,000	
Ground Infrastructure	Ground Infrastructure OPEX	$590,650,000	$899,230,000
	Ground Infrastructure CAPEX	$308,580,000	
Traffic Management Systems	Cost OPEX	$243,508,000	$416,916,000
	Cost CAPEX	$173,408,000	
UAM Operators	Passenger Revenues	$5,638,546,000	$8,601,009,000
	Medevac Revenues	$1,762,562,000	
	Cargo Revenues	$1,199,901,000	
Vehicles	Vehicle Manufacturing	$4,878,672,000	$6,511,523,000
	Vehicle Purchases	$1,632,851,000	
Virginia Total		**$16,428,678,000**	**$16,428,678,000**

Source: (Virginia Innovation Partnership Corporation, 2023)

In September of 2021, a white paper was published for the state of Arkansas documenting the economic impact of AAM in the state over a 25-year period from 2021 to 2045 (NEXA Advisors, 2021). The forecast calls for 58,057 passengers between 2020 and 2024 and 21,673,104 for the 23-year forecast period. The economic impact over the first five years is expected to be $109.5 million, with the total over the 25-year period at $3.6 billion.

Table 6-12 shows the total expenditures or revenues for these different supply chains during the next 25 years. The 21.6 million passengers, along with cargo operations and medevac operations, are expected to drive total revenues to more than $2.5 billion through 2045. Capital investment and operating expenses for the ground infrastructure, vehicles, and traffic management services add an additional $1 billion. These are shown in more detail below.

Table 6-12: AAM Revenues/Expenditures in Arkansas, 2021-2045

		2020-2024	2041-2045	2020-2045	Total by Supply Chain
Demand (Passengers)		58,057	13,508,627	21,673,104	
Ground Infrastructure	Ground Infrastructure OPEX	$ 7,984,229	$ 69,161,419	$ 192,379,619	$ 277,293,590
	Ground Infrastructure CAPEX	$ 21,122,300	$ 8,692,208	$ 84,913,971	
Traffic Management Systems	Cost OPEX	$ 288,025	$ 20,579,141	$ 52,099,912	$ 89,374,176
	Cost CAPEX	$ 4,341,001	$ 6,084,297	$ 37,274,264	
UAM Operators	Passenger Revenues	$ 14,546,342	$ 605,651,327	$ 1,265,554,192	$ 2,575,014,205
	Medevac Revenues	$ 13,801,247	$ 202,240,124	$ 660,832,707	
	Cargo Revenues	$ 24,599,759	$ 245,807,792	$ 648,627,306	
Vehicles	Vehicle Purchases	$ 22,865,980	$ 182,595,038	$ 618,244,393	$ 618,244,393
Arkansas Total		**$ 109,548,883**	**$ 1,340,811,346**	**$ 3,559,926,364**	**$ 3,559,926,364**

Source: Advanced Air Mobility Comes to Arkansas. (NEXA Advisors, 2021)

Conclusions

With the scarcity of available data (as the AAM industry is in its infancy), national-level and other state-level economic impact analyses can provide some insight and correlation into the level of activity that may be seen in Georgia. While the demographic makeup and economic profiles of Arkansas, Ohio, and Virginia are different from Georgia, the projected economic impacts from those states can provide an order-of-magnitude-level understanding of what might be expected in Georgia. **Table 6-13** shows population and gross domestic product comparisons for the three states and the country as a whole.

Table 6-13: Population and GDP of Arkansas, Georgia, Ohio, and Virginia

State	Population	Percent of U.S.	Gross Domestic Product ($ millions)	Percent of U.S.	GDP per Capita ($)
Arkansas	3,045,637	0.91%	166,488	0.65%	$54,664.43
Georgia	10,912,876	3.27%	$762,096	2.96%	$ 69,834.57
Ohio	11,756,058	3.53%	$829,594	3.22%	$ 70,567.36
Virginia	8,683,619	2.61%	$654,573	2.54%	$ 75,380.21
United States	333,287,557	100%	$25,723,941	100%	$ 77,182.42

Source: U.S. Census Bureau (2022); Bureau of Economic Analysis (2022 3Q).

The population and GDP in Georgia as a share of the nation—and with respect to Arkansas, Ohio, and Virginia—can provide some frame of reference for the level of AAM activity, given how population can be correlated with economic activity. With the closeness of their economic profiles, Ohio and Virginia are projecting similar 2040 trip estimates in the 7.7 to 7.8 million range. Because every state's economy is driven by different factors, a true comparison is difficult. Further, every economic impact study uses different methodologies, assumptions, and constraints, and each report results in different time periods and with different metrics, further complicating comparisons. However, the results can be useful (especially on the state and city level) when considering what AAM might look like and what operational frequencies may be possible during the next 10-20 years.

7. Heliport Inventory and Analysis for AAM Application

7.1 Heliports

The early stages of AAM will rely on existing aviation infrastructure, including airports and heliports. This chapter aims to inventory and assess the current state of Georgia's heliports and to determine their compatibility with the FAA's standards for vertiports. First, the chapter compares heliports to vertiports and explains the differences in design criteria and typical uses. Next, the chapter inventories the existing heliports in Georgia to determine the number available, their use, and their ownership. Last, the chapter will provide a compatibility analysis for those heliports in the state with the greatest potential for use as vertiports.

7.2 Heliports vs Vertiports

It is important to note that while heliports and vertiports bear many similarities between their landing geometry and approach and departure surfaces, they are not always interchangeable. **Table 7-1** demonstrates the key design features of vertiports as established in FAA EB, Vertiport Design, (Federal Aviation Administration, 2022) compared to FAA AC 150/5390-2D, Heliport Design, (Federal Aviation Administration, 2022) and specifically design standards for general aviation heliports and transport heliports.

The key components of the landing area for both a heliport and a vertiport are the TLOF, the FATO, and the SA. The TLOF is a load-bearing, generally paved area centered in the FATO, on which the VTOL aircraft performs a touchdown or liftoff. The FATO is a defined area over which the VTOL aircraft completes the final phase of the approach to a hover or a landing and from which the aircraft initiates takeoff. The SA is a defined area surrounding the FATO intended to reduce the risk of damage to VTOL aircraft unintentionally diverging from the FATO (Federal Aviation Administration, 2022).

As shown in **Table 7-1**, there are several differences in the landing geometry between general aviation heliports, transport heliports, and EB 105 vertiports. Generally, a general aviation heliport has the least demanding landing geometry, and EB 105 and the transport helicopter design standards are more demanding. The more conservative guidance for vertiports under EB 105 is because there was very limited data on the performance of these aircraft at the time of its publication—none have received FAA certification.

Table 7-1: Primary Differences between VFR Heliport Design Standards and EB 105.

Units in Feet	**Heliport Design AC GA Heliports**	**Heliport Design AC Transport Heliports**	**FAA EB 105**
TLOF (centered w/i FATO)			
Width	0.83D	0.83D but not less than 50’	1D
Length	0.83D	0.83D but not less than 50’	1D
FATO (weight-bearing)			
Width	1.5D	1.66D (but not less than 100 ft)	2D
Length	1.5D	1.66D but not less than 100 ft	2D
Safety Area	0.28D but not less than 20 ft*	0.42D but not less than 30 ft	.5D
Primary Surface	Coincides with FATO		Coincides with FATO
VFR Approach/Departure	V 8:1 slope - FATO IW - 4000 L - 500 OW	V 8:1 slope - FATO IW - 4000 L - 500 OW	V 8:1 slope - FATO IW - 4000 L - 500 OW

Units in Feet	Heliport Design AC GA Heliports	Heliport Design AC Transport Heliports	FAA EB 105
Surface (two minimum separated by at least 135°)			
VFR Transitional Surface	V 2:1 to 250 from the centerline of primary & app. surface	V 2:1 to 250 from the centerline of primary & app. surface	2:1 slope 250 from CL of primary & app. surface

Source: (Federal Aviation Administration, 2022) D = controlling dimension: the diameter of the smallest circle enclosing the aircraft projection on a horizontal plane, while the aircraft is in the takeoff or landing configuration, with rotors/propellers turning,

The landing geometry for a vertiport is based on the design aircraft—the largest eVTOL aircraft that is expected to operate at the vertiport. Engineering Brief 105 specifies that the TLOF is 1D of the aircraft where D is the controlling dimension[1] of the aircraft. The FATO is 2D, and the Safety Area is 3D (Federal Aviation Administration, 2022). **Table 7-2** displays the dimensions of many early entrant eVTOLs, the estimated controlling dimension of the aircraft, and the minimum TLOF, FATO, and SA that would be needed for each. Because current AAM aircraft designs are proprietary, the exact controlling dimensions may differ from the dimensions shown in **Table 7-2**.

Table 7-2: Early Entrant eVTOL Dimensions

PLATFORM	LENGTH x WIDTH FT	Estimated Controlling Dimension (D) FT	Minimum TLOF / FATO / SA (FT)
Multicopter			
Ehang 216	18 x 18	18	18 / 36 / 54
Lift Hexa	18 x 18	18	18 / 36 / 54
Volocopter Volocity	37 x 37	37	37 / 74 / 111
Lift and Cruise			
Airbus City NextGen	NA x 50	50	50 / 100 / 150
BETA Alia-250	NA x 50	50	50 / 100 / 150
Eve	43 x 36	43	43 / 86 / 129
Wisk Generation 6	NA x 50	50	50 / 100 / 150
Vectored Thrust			
Archer Midnight	NA x 47	47	47 / 94 / 141
Lilium Jet	25 x 46	46	46 / 92 / 138
Joby S-4	28 x 36	36	36 / 72 / 108
Vertical Aerospace VX4	42 x 49	49	49 / 98 / 147

Source: (OEM Websites, 2023)

The largest eVTOL aircraft in the table above have an estimated controlling dimension of 50 feet. An agnostic vertiport, one that is not exclusive to a specific aircraft design, should be built with a minimum length and

[1] The controlling dimension is the diameter of the smallest circle enclosing the VTOL aircraft projection on a horizontal plane, while the aircraft is in the takeoff or landing configuration, with rotors/propellers turning, if applicable. (Federal Aviation Administration, 2022, p. 9)

width of 50 feet for the TLOF, 100 feet for the FATO, and 150 feet for the SA. When the TLOF, FATO, and SA are circular, these dimensions are the same for the diameter. The dimensions and total square feet associated with these areas are shown in **Table 7-3.**

Table 7-3: Minimum Vertiport Landing Dimensions

Landing Feature	Total Size (feet)	Total Square Feet
TLOF	50 x 50	2,500
FATO	100 x 100	10,000
Safety Area	150 x 150	22,500

Most heliports today consist of a single pad with a based helicopter that operates a certain mission and then returns to that heliport. A hospital heliport, for example, may have its own aircraft based at the heliport (or in other cases, use a medivac company that is based at a nearby airport), to fly air ambulance missions to the hospital; the aircraft then either remains at the hospital or returns to base at the nearby airport. A hospital heliport, or any single-pad heliport, has limited potential for high-volume or high-tempo operations due to the inability of the aircraft to land, taxi away from the landing area, and make room for additional aircraft. Instead, the aircraft is forced to land at the landing area and remain there until the mission is complete or refueling takes place (if needed). This is very different from the concept of operations for many eVTOL OEMs, which would require a commercial vertiport to have a place for aircraft to taxi away from the landing area to a terminal or charging station where it can recharge and load/unload passengers or cargo, opening the TLOF for other arrivals or departures. High-capacity heliports like this are rare and do not readily exist.

7.3 Heliports in Georgia

The FAA's Airport Data and Information Portal (ADIP) (Federal Aviation Administration, 2023) has records for 127 heliports in Georgia. Two of these heliports are the landing pads at DeKalb-Peachtree Airport (PDK) and Atlanta Regional Falcon Field (FFC), which are both public-use airports and thus are not included in the heliport inventory.

The remaining heliports in Georgia are all private use—100 are privately owned and private use and 25 are publicly owned but only available for private use. There are four heliports with multiple TLOFs. Among them, three have two TLOFs each and one has three TLOFs. During the analysis, each TLOF was considered as an individual site because they may vary in size or compatibility with other TLOFs at the same location.

The fact that every standalone heliport in Georgia is private use has significant implications for this analysis.

- First, unlike public-use airports that are open to the public for services like airline transportation, air cargo, general aviation, flight training, etc., private-use facilities are not typically open to the public and are not located in areas designed to support a diverse array of operations. A heliport atop a hospital, for example, is limited to operations by the hospital only for services like patient or organ transport.
- Second, most private use facilities are in areas specific to the heliport's intended use. For example, a police heliport is usually built at or near a police station. In each of these cases, converting these heliports into vertiports is unlikely and would serve a limited purpose. If the heliport could meet the landing dimensions needed for eVTOL aircraft, it could theoretically be converted into an AAM landing facility for those specific users but not reasonably adapted into a facility supporting commercial eVTOL operations for the public. These factors significantly limit the value of converting most private-use heliports into vertiports.

For this analysis, the team used ADIP records and Google Earth to categorize all the heliports in Georgia into service categories by ownership and/or use. For example, heliports associated with hospitals were grouped into a category for medical facilities, and heliports on private, residential lots were grouped into a category for individual/residential facilities.

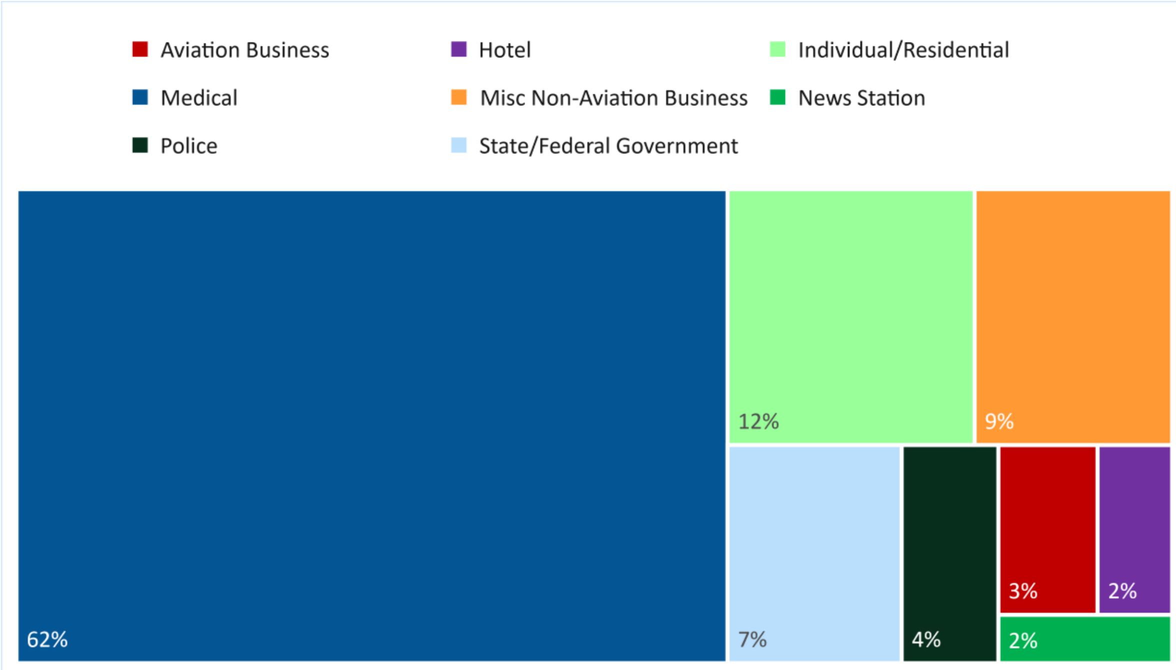
Table 7-4 shows categories, an explanation of what heliports were grouped into which category, and the number and percentage of heliports in that category. **Figure 7-1** graphically displays the proportion of heliports in each category, and **Figure 7-2** displays their locations across the state.

Table 7-4: Georgia Heliports by User Category

Category	Explanation of Category	Count	Percentage of Total
Aviation Business	Helicopter tour or aircraft manufacturing companies	4	3%
Hotel	At or adjacent to hotels or lodging	3	2%
Individual/Residential	On residential private property	15	12%
Medical	At or adjacent to hospitals for patient transport	80	62%
Miscellaneous Non-Aviation Business	At insurance, real estate, utilities, or other companies	12	9%
News Station	At the news station campus	2	2%
Police	At police department	5	4%
State/Federal Government	Owned/operated by state or federal government (including military)	9	7%
Sum of Categories		**130**	**100%**

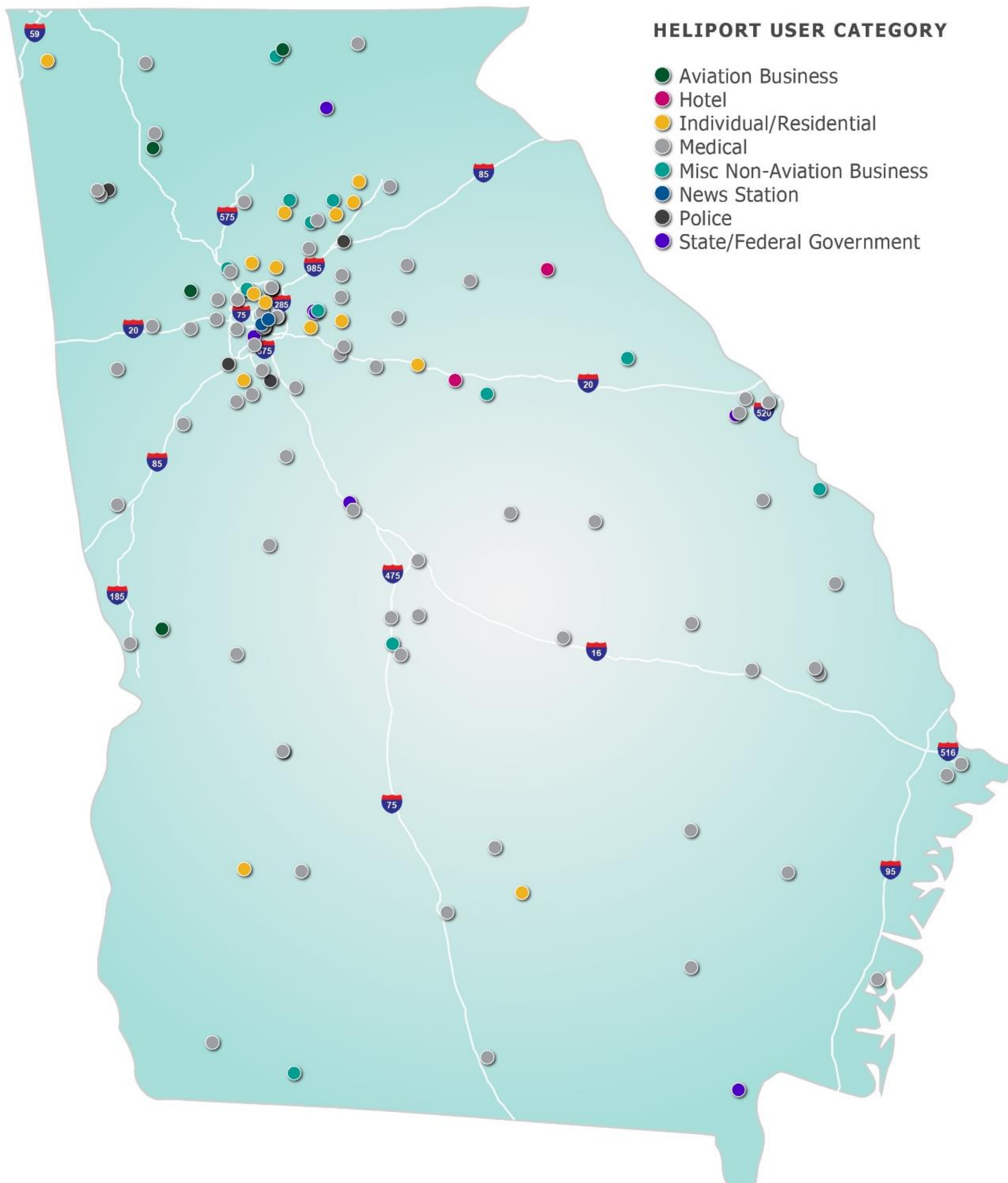
Source: (Federal Aviation Administration, 2023), Woolpert Analysis

Figure 7-1: Georgia Heliport Facilities by User Category



As shown above, heliports across Georgia are most used for medical purposes, making up 62 percent of the facilities in the state. The next largest category, at 12 percent, is individual/residential. The remaining categories each make up less than ten percent and feature a combination of non-aviation businesses, police departments, and state- and federally-owned facilities.

Figure 7-2: Heliports by User Category across Georgia



Source: (Federal Aviation Administration, 2023), Woolpert Analysis

7.4 Heliport Compatibility Analysis

A desktop analysis was performed on the heliports with the most potential to be converted to vertiports. This analysis consisted of the following steps:

1. Determine the size of the heliport's TLOF, FATO, and the SA of the TLOF.
2. Compare those sizes to the EB 105 sizes for a TLOF, FATO, and SA for an agnostic eVTOL with a controlling dimension of 50 feet.
3. Perform an obstruction and feasibility analysis on those heliports that were within 5 feet or less of those EB 105 standards.

As an initial viability test, the team used the ADIP data to identify TLOFs that were within five feet of the minimum dimensions needed for a TLOF for an eVTOL with a controlling dimension of 50 ft. (i.e., a TLOF of 50 feet by 50 feet) The five-foot buffer was used to not exclude sites that could comply with a minor redesign. If the TLOF met or exceeded this threshold, the FATO, SA, and surrounding location were evaluated in a similar fashion for a secondary viability test.

Table 1-1 in the **GDOT AAM Study – Heliport Analysis Report** details each heliport in the state along with its user category, reported TLOF dimensions, and the initial viability based on the reported TLOF dimensions. As shown, 64 of the 130 TLOFs met the TLOF dimension threshold cutoff, while 66 did not. Next, the team examined each of the 64 TLOFs that passed that initial compatibility test. Using Google Earth imagery, the team identified the center of the TLOF and measured a circle with a 75-foot radius to evaluate if there was adequate space for a correctly sized TLOF, FATO, and SA (see **Table 7-3**).

The team also used aerial imagery to qualitatively assess whether the site—considering the facility's location and users—could be converted into a vertiport. Some sites, for example, are extremely remote or simple turf areas in an individual's backyard. Sites like these were eliminated because their use is inhibited by their function. The results of this analysis for the 64 remaining sites are included in **Table 1-2** in the **GDOT AAM Study – Heliport Analysis Report.**

Only nine of the 64 TLOFs that passed the initial viability test also passed the secondary viability test. These heliports are consolidated in **Table 7-5**.

Table 7-5: Remaining Viable Heliports

Facility Name	Loc Id	User Category	TLOF Dimensions	Viability	Reason
Caffrey	00GE	Aviation Business	125x95	Yes	Owned by geospatial firm. Multiple landing pads and adequate space.
Central State Hospital	6GA6	Medical	50x50	Yes	Ability to be right-sized with minor redesign.
East Georgia Rgnl Medical Center	GA28	Medical	90x90	Yes	Ability to be right-sized with minor redesign.
Interstate North	GA54	Misc Non-Aviation Business	85x85	Yes	Limited room for expansion but otherwise viable landing facility with access to nearby attractions.
Ramada Inn Antebellum	GA05	Hotel	400x400	Yes	Grass area between several hotels.

Facility Name	Loc Id	User Category	TLOF Dimensions	Viability	Reason
Smyrna Hospital	40GA	Medical	50x50	Yes	Ability to be right-sized with minor redesign.
South Fulton Medical Center	GA71	Medical	74x74	Yes	Ability to be right-sized with minor redesign.
Stone Mountain Park Skylift	92GA	State/Federal Government	110x110	Yes	While TLOF is smaller than reported, it's in a large lot and there is adequate space to expand.
Wayne Memorial Hospital	39GA	Medical	60x60	Yes	Ability to be right-sized with minor redesign.

Source: (Federal Aviation Administration, 2023), Google Earth, Woolpert Analysis

It is worth noting again that all these facilities are private-use. Any conversion of the current facility into a vertiport would be limited to use by the heliport owner and authorized users only, without modifications to the existing property ownership or use structure. Deeming a facility "viable" simply means that it meets minimum characteristics that could enable eVTOL operations.

These nine facilities were further investigated using GIS and Google Earth software to analyze the site for airspace, ingress and egress, and obstructions. The following GIS layers were used for this analysis:

- Controlled Airspace: FAA-controlled airspace is atmospheric space of specifically defined dimensions described in height above median sea level (MSL) or height above ground level (AGL). In controlled airspace, air traffic control services are provided to flights conducted under IFR or VFR in accordance with an airspace. Specific requirements associated with different classes of controlled airspace are explained in the heliport's compatibility analysis when applicable.
- Approach and Departure Surface Airspace Cone: EB 105 specifies specific airspace requirements for the approach and departure paths of eVTOL aircraft to a vertiport. To establish the viability of an EB 105-compliant ingress and egress at each heliport, a cone of airspace was created around it originating at the outer edge of the FATO and extending outward at an 8:1 slope for 4,000 feet. To determine if there are penetrations to that surface, two steps were taken:
    - Tall Structures Penetration: The FAA Digital Obstacle File (DOF) (updated every 56 days) describes all *known* obstacles of interest to aviation users in the United States. This database, however, does not capture *all* obstacles and is mostly focused on obstacles that affect traditional airports. The obstacles in this database were mapped for this analysis, and any that penetrated the vertiport approach and departure surface airspace cone were highlighted and labeled.
    - Visual Obstructions/Penetrations: Because the FAA DOF does not capture all obstacles, 3D imagery from Google Earth was used to identify any obstacles that visually penetrated the airspace cone. Google Earth terrain and 3D building layers provided a visual representation of trees, hills, buildings, and other obstacles at six of the nine viable sites. At the three sites without this data, planning-level assumptions were developed to create 3D visualizations of possible penetrations. These assumptions are as follows:

- Trees: Georgia's native pines can grow to heights of 100 feet or more (A Guide to Pine Trees in Georgia, 2023). While not all trees in Georgia reach this height, it provides a simple, "high" estimate to identify places where trees may penetrate the airspace cone. A height estimate that is too low could provide a false sense of a clear approach and departure surface, while setting the height of the protrusion too high could result in surface penetrations that would only exist in extreme circumstances. While no height threshold is flawless, 100 feet is used for this analysis as a middle ground.
- Buildings: Building heights vary dramatically depending on the number of floors as well as the height of the floors. Commercial building codes can provide an estimate of how tall a typical floor is for the buildings surrounding these sites. While the typical floor height can vary widely, a broad assumption of 14 feet per floor (Iqbal, 2022) provides a planning-level estimate for building height. To account for slight variations and higher-than-expected building heights, 15 feet was used.
- Other: A visual review was done to identify nearby objects that may theoretically penetrate the surface, and these were documented as potential obstructions.

For each of these instances, it is important to note that 3D buildings and imagery from Google Earth can come from numerous sources and, while they provide a visual representation of the buildings and terrain in an area, they should not be considered the final authority on an obstacle's presence at a site. Should any of these sites be converted into a vertiport, a traditional aviation survey should take place to formally identify any penetrations to the vertiport's approach and departure surfaces.

The detailed compatibility analysis for each of the nine heliports is found in in the **GDOT AAM Study – Heliport Analysis Report.** A summary of the findings is shown in **Table 7-6.**

Table 7-6: Summary of Heliport Compatibility Reports

Heliport Name	User Category	Summary of Findings
Caffrey (00GE)	Aviation Business	• Minor redesign and tree trimming needed for landing area. • No major airspace issues. • Multiple landing pads and support hangars available. • Could support air cargo or public service use cases if needed. • Privately owned and operated, permission or sale required for eVTOLs.
Central State Hospital (6GA6)	Medical	• Minimal redesign needed to meet EB 105 standards. • Uncontrolled airspace means minimal restrictions on operations. • Clear ingress and egress could likely be achieved with minor clearing or trimming of trees.

Heliport Name	User Category	Summary of Findings
		• Assuming electric needs are met, this facility could support air medical eVTOL operations.
East Georgia Rgnl Medical Center (GA28)	Medical	• Minor expansion of TLOF and FATO needed to meet EB 105 standards; Minor redesign of road and/or parking lot needed to accommodate SA. • Numerous penetrations in the 8:1 cone, but penetrations involving trees appear minimal and the facility can likely accommodate clear approach and departure paths with at least 135° separation with minor obstruction removal or marking. • The heliport can be converted to a vertiport, but its capabilities would be limited to the low-volume medical operations that the facility currently accommodates.
Interstate North (GA54)	Misc Non-Aviation Business	• Minor expansion of TLOF and FATO needed to meet EB 105 standards; tree clearing/trimming would be required, and grading of ground required. • Significant airspace issue; Class D airspace and location off runway would require significant coordination with air force base and FAA. • Numerous penetrations in the 8:1 cone, especially close to the landing area. If trees are cleared, minimal penetrations from buildings. • The heliport would face significant barriers if efforts were made to convert to a vertiport.
Ramada Inn Antebellum (GA05)	Hotel	• Redesign of the adjacent parking lot and relocation of all landing areas to the center of grass needed to meet EB 105 standards. • Uncontrolled airspace means minimal restrictions on operations.

Heliport Name	User Category	Summary of Findings
		• Clear ingress and egress are unlikely to be achieved due to hotel and tree penetrations in nearly all directions.
Smyrna Hospital (40GA)	Medical	• Minor redesign of landing area needed to meet EB 105 dimensions; clearing/trimming of trees nearby. SA would directly abut the hospital building. • Significant penetrations in all directions. While trees could be trimmed, hospital building and nearby residential uses would still be significant penetrations. • Site unlikely to reasonably establish clear ingress and egress and thus is not a feasible site for conversion.
South Fulton Medical Center (GA71)	Medical	• Redesign of landing area needed to meet EB 105 dimensions; would require relocation of landing area or significant changes to tunnel/road directly north. • Class B airspace is strict and requires clearance. • Trees could be trimmed to create a clear ingress and egress, but space for landing area likely limits use to small eVTOLs.
Stone Mountain Park Skylift (92GA)	State/Federal Government	• Minor redesign of landing area needed to meet EB 105 dimensions; clearing/trimming of trees nearby. Stone Mountain can be avoided on approach/departure. • A possible use case transporting tourists exists, but accommodations would have to be made to ensure Public Safety has access. • Should the facility be converted, electrical supply and fire safety should be considered.
Wayne Memorial Hospital (39GA)	Medical	• Minimal redesign needed to meet EB 105 standards, but would impact the parking lot.

Heliport Name	User Category	Summary of Findings
		• Uncontrolled airspace means minimal restrictions on operations. • Clear ingress and egress could likely be achieved by clearing or trimming trees in at least one direction. • Assuming electric needs are met, this facility could support air medical eVTOL operations

7.5 Conclusions

The Heliport Inventory and Analysis systematically assessed existing heliports in Georgia, exploring their potential conversion into vertiports for accommodating eVTOL aircraft operations. Out of the 125 heliports in Georgia, all were identified as private-use facilities. This implied that any conversion or modification would impact only the users of that particular facility unless there were changes in public access policies.

The heliports were primarily categorized by usage, with a significant number serving hospital/medical transport purposes. Other heliports were utilized by both aviation and non-aviation businesses, and some were located at residential properties. To identify the most promising candidates, the analysis considered factors such as facility size and general feasibility.

Following the initial assessment, nine heliports emerged as having the greatest potential. A subsequent, more detailed analysis was conducted on these nine sites, and the specific findings for each are summarized in **Table 7-6.**

8. Airport Compatibility Reports

The FAA's Innovate 28 Implementation Plan suggests that initial AAM operations will use existing infrastructure at general aviation airports (Federal Aviation Administration, 2023). While most airports have existing airspace and approach and departure corridors, this chapter examines ten public-use, publicly-owned airports for compatibility with the potential addition of eVTOL operations and facilities. Although airports may have existing airspace, further study is needed to determine if additional infrastructure is required to service AAM aircraft, such as electric charging stations and related utilities.

This chapter addresses these issues, including minimum infrastructure and the estimated cost of installing electric charging stations statewide, the potential relationship between Georgia's airport infrastructure that can align with Georgia's NEVI Plan, and revenue capture methods available with electric charging and a range of fees charged to users based on established metrics. This chapter includes best practices for revenue generation from the use of electric chargers for aircraft and surface vehicles, as well as a discussion on other alternative fuel technologies and their inclusion in infrastructure planning.

8.1 Airports and AAM

Georgia's public airport system consists of eight commercial service airports and 94 general aviation airports. Ten of these airports were selected to identify their potential compatibility to support AAM aircraft. These airports are as follows:

- Athens/Ben Epps Airport.
- Augusta Regional Airport.
- DeKalb-Peachtree Airport.
- Fulton County Executive Airport.
- Savannah/Hilton Head International Airport.
- Middle Georgia Regional Airport.
- Columbus Airport.
- Paulding Northwest Atlanta Airport.
- Dalton Municipal Airport.
- Jackson County Airport.

To assess an airport's compatibility for AAM, several factors must be considered. A vital factor is the airport's capacity, as this dictates whether eVTOLs can use the existing runways, taxiways, and ramp space or if new landing infrastructure is needed. Additionally, the airport must be equipped to provide electric aircraft charging and adhere to fire safety protocols for electric aircraft. Lastly, it is important to ensure that supporting infrastructure—such as weather monitoring tools, broadband/data infrastructure, and ADS-B receivers—is in place. These factors are detailed in the following four subsections. The Compatibility Report for each airport listed above is found in the **GDOT AAM Study - Select Airports Analysis Report.**

Airport Capacity and Landing Infrastructure

While vertiports are the focus of new eVTOL-related infrastructure, airports are already equipped with much of the infrastructure needed to support eVTOLs. An airport can either integrate eVTOL operations into its existing traffic flow, or it can segregate eVTOL operations at a dedicated landing facility. The first option, integration, is the simplest because many of these eVTOL aircraft can land conventionally, flying the runway's approach and landing like fixed-wing aircraft. Alternatively, eVTOLs can land at airports as helicopters do today, by following airport protocols and landing vertically at their intended destination on the apron or on movement areas.

The second option is to construct a facility that segregates eVTOL from the rest of the airport's operations. Building and locating a vertiport on airport property can be done so that it operates independently of the airport's runway, thus minimizing the impact on the airport's capacity.

To determine if segregated operations and an on-airport vertiport are feasible, airport capacity is analyzed using Annual Service Volume (ASV) estimates found in FAA AC 150/5060-5, Airport Capacity and Delay.

Should an on-airport vertiport be co-located in an airport, EB 105 is the current federal guidance for the design of that facility. A minimally built vertiport at an airport does not necessarily require a new terminal or additional facilities beyond the landing area itself. The required facilities include:

- Touchdown and Liftoff Area (TLOF): a load-bearing, generally paved area centered in the FATO, on which the aircraft performs a touchdown or liftoff.
- Final Approach and Takeoff Area (FATO): a defined, load-bearing area over which the aircraft completes the final phase of the approach to a hover or a landing, and from which the aircraft initiates takeoff.
- Safety Area (SA): a defined area surrounding the FATO intended to reduce the risk of damage to aircraft accidentally diverging from the FATO.

Additional details regarding EB 105 can be found in **Chapter 4** of this study, **Best Practices for AAM Landing Area Regulation and Safety.** The brief does, however, provide specific guidance for on-airport vertiports. This guidance is summarized in **Table 8-1**.

Table 8-1: EB 105 Guidance for On-airport Vertiports

Summarized Guidance	Practical Implications
All federally obligated airport sponsors are to provide reasonable and not unjustly discriminatory access to all aeronautical users.	Any vertiport designed at a federally obligated airport should be built agnostically, so the landing facilities can accommodate a variety of eVTOLs. Thus, an on-airport vertiport should have a minimum of a 50-foot diameter TLOF, 100-foot diameter FATO, and 150-foot diameter SA (including the FATO and TLOF). These dimensions account for nearly all eVTOL aircraft in development.
Locate the TLOF away from but with access to fixed-wing aircraft movement areas (runways, taxiways, etc.)	Any vertiport on an airport should be located outside of these movement areas. Aerial imagery can be used to ensure these areas are avoided.
The center of the FATO should be located outside of all object free areas, safety areas, runway protection zones, and safety-critical navigational aid areas.	These areas should be mapped to ensure that vertiport siting exercises exclude these areas.
The center of the FATO should be located at least 300, 500, or 700 feet from the centerline of the runway, depending on the weight of the critical aircraft for that runway.	The critical aircraft of each runway (or the runway design code if critical aircraft is not available) at an airport should be used to determine the appropriate vertiport minimum distance from that runway, as provided in EB 105. This area should be mapped and excluded from vertiport siting exercises.

Source: (Federal Aviation Administration, 2022), Woolpert Analysis

As such, the following areas were avoided in the vertiport siting exercise at each airport in this analysis:

- Runways and taxiways. Aerial imagery from Google Earth displays these movement areas.
- Runway safety area (RSA), runway object free areas (ROFA), taxiway object free areas (TOFA), and runway protection zone (RPZ). These areas were mapped using each airport's airport layout plan.
- Vertiport minimum distance. This area was mapped based on the runway's critical aircraft or runway design code.
- FAR Part 77 Surfaces and Approach and Departure Surfaces from FAA AC 150/5300-13B, Airport Design. These surfaces were not mapped, but care was taken to avoid sites that may interfere with those surfaces, primarily by avoiding sites interfering with the RPZ and areas beyond the RPZ.

Electric Aircraft Charging

An eVTOL aircraft requires a substantial amount of electricity to charge the batteries. There are two components to electrical power for electric aircraft charging: three-phase electricity, and adequate supply. Three-phase electricity is mainly used to power electric motors and other heavy loads and is necessary for high-capacity electric charging stations as well.

A 2019 study conducted by Black & Veatch found that eVTOLs currently in development can be charged at a maximum of 350kW. However, the study recommends utilizing 600kW chargers to futureproof the infrastructure (Black & Veatch, 2019). It is important that airports consult the local electric utility to determine the current type and supply of electricity, as well as approximate levels of effort and costs associated with upgrading these components if needed.

BETA Technologies, an OEM of eVTOLs and charging cubes for electric cars and aircraft, is building a network of charging stations at airports across the country. A charging station has been installed at Augusta Regional Airport, and plans are underway to install four additional chargers at airports across the state. The specifications for their charging equipment are shown in **Table 8-2.**

Table 8-2: BETA Charge Cube Specifications

Specification	Unit
AC Voltage Connection	480 Vac, 3 Phase, 60 Hz
AC Grid Current	420 Amps
Continuous Power	320 kW
Battery Charge Range	Up to 1,000 Vdc
Continuous Charge Current	350 Amps
Payment Methods	Phone App + Plug and Charge
Charging Protocol	CCS

Source: (Beta Technologies, 2023)

BETA utilizes a universal charging standard that allows the charger to be used on any electric vehicle compliant with the Combined Charging System (CCS1) standard. Electric aircraft operations at any airport will be limited without charging infrastructure. If the airport lacks charging stations, electric aircraft must plan for a return flight to a charging-equipped location to avoid being stranded. Given the existing range limitations of eVTOL aircraft, onsite charging is a must for any facility that hopes to serve electric aircraft.

As noted, the power demands for this level of charging are significant, and many airports will need to consider upgrades to their existing power supply. Onsite charging most commonly comes in the form of stationary chargers, but mobile charging stations on trucks or vans may find a market during surge periods or in remote areas with limited access to three-phase electricity.

When considering the siting of an electric aircraft charging station, the airport should consider the following factors:

- The charger should be located near the landing area and the spot where passengers disembark to reduce power consumption taxiing to and from those areas.
- The parking areas for the charger should be spacious enough to accommodate the aircraft taxiing to and from the station, including a sufficient taxiing turn radius.
- The charging station should be in an area near existing electric power so that minimal redesign or new electrical lines are needed.

Electric Fire Safety

Traditional Aircraft Rescue and Firefighting (ARFF) is designed around combustion engines and traditional fuel. Electric aircraft powered by lithium-ion batteries will have specific emergency response needs, which have yet to be fully established. Engineering Brief 105 includes details of on-site safety elements for vertiports, including firefighting considerations. It notes that prior FAA research on small lithium battery cells found that water and other foam fire extinguishing agents were more effective for suppressing lithium battery fires than gas or dry powder extinguishing agents, though it has yet to be determined if the case is the same for the large battery packs found in eVTOLs.

Official firefighting protocols for eVTOL aircraft are still being developed, and these protocols may differ from aircraft to aircraft. Still, several steps can be taken to best plan for electric aircraft firefighting at an airport.

The National Fire Protection Association (NFPA) is a U.S.-based international nonprofit that develops standards and guidance for fire safety. NFPA 418, Standards for Heliports, is the NFPA's guidance for fire safety at heliports (National Fire Protection Association, 2021). This guidance is currently being updated to account for electric aircraft and the electrical hazards and fire safety standards associated with them. This update is expected to be published in 2024, before the expected entrance into service targets of leading eVTOL OEMs. When this guidance is published, airports should adopt the standards and guidance in this report.

Operators of Part 139 airports must provide ARFF services during air carrier operations that require a Part 139 certificate. Airport management should coordinate with onsite ARFF to develop a procedure for electric aircraft battery fires, using existing best practices for fire safety.

Operators of non-Part 139 airports are not required to have onsite firefighting services and instead typically have an arrangement with the sponsoring local government to provide aircraft firefighting services. Airport management should coordinate with local firefighting officials to develop a procedure for a response to an electric aircraft fire at the airport.

Supporting Infrastructure

Several other components of supporting infrastructure that already exist at some airports are weather observation technology, ADS-B receivers, and high-speed data/broadband.

The Surface Weather Observation Program is a joint effort of the National Weather Service (NWS), the FAA, and the Department of Defense, and it serves as the nation's primary surface weather observing network. It is designed to support weather forecast activities and aviation operations and, at the same time, support the needs of the meteorological, hydrological, and climatological research communities. Airports typically have either an Automated Weather Observation Station (AWOS) or an Automated Surface Observation Station (ASOS). Without on-airport weather reporting, charter/air taxi flights may not be allowed to take off or land in instrument (poor) weather conditions. Any airport without either an AWOS or ASOS should consider installing one on their airfield to support both AAM and conventional operations.

The second component of supporting infrastructure for AAM is Automatic Dependent Surveillance-Broadcast (ADS-B). This NextGen surveillance is transforming all segments of aviation due to its capabilities in real-time precision, shared situational awareness, and advanced applications for pilots and controllers alike (Federal Highway Administration). As some aircraft (including electric aircraft) move gradually towards remote and/or autonomous piloting systems, ADS-B receivers at airports will ensure that these aircraft are tracked in a safe and efficient way. Airports without ADS-B receivers should consider installing them.

The third component of supporting infrastructure is high-speed data/broadband. This infrastructure is not critical for electric aircraft to operate, but it is considered a standard for site readiness and will ultimately enable autonomous aircraft operations. Airports without high-speed data/broadband should work with local internet providers to provide access to this infrastructure.

8.2 Electric Infrastructure for Airports

To plan for adequate airport charging infrastructure to support the emerging AAM industry, it is necessary to: identify what is needed, confirm sufficient capacity exists from utility providers, plan a timeframe for installation, determine who will own and operate the infrastructure, investigate how much the infrastructure will cost, and identify who will pay for it. This planning will require a collaborative partnership between private sector OEMs, airport infrastructure companies, local utilities, and airport owners.

Like Georgia, Washington, and Ohio are currently exploring planning requirements. In October 2022, the University of Washington published the Washington Electric Airport Feasibility Study (Transportation W. D., 2022). The study analyzed the electric grid near two regional airports—Paine Field and Grant County International Airport in Washington State—and determined that the local utilities had sufficient capacity to meet the anticipated demand for electric aircraft during the next 10 years.

The Colorado Department of Transportation's Division of Aeronautics contracted in early 2023 with the National Renewable Energy Lab (NREL) to conduct the Colorado Alternatively Powered Aircraft Airport Infrastructure Study. Similar in scope to GDOT's AAM Study, the effort seeks to define the landscape of issues associated with integrating alternatively-powered aircraft in existing airport infrastructure, including estimates on charging infrastructure demand, costs, and potential funding sources. The study is slated for completion in the fall of 2024.

This section outlines the current and forecasted utility supply and demand for Georgia, general charging requirements, estimated costs for potentially installing electric aircraft charging infrastructure on 102 of Georgia's existing publicly-owned, public-use airports, and a discussion of current industry revenue models for electric aircraft and vehicle charging.

Electric Utility Regulation and Resource Availability

The Public Service Commission (PSC) is the state's regulatory and oversight agency for electric utilities, comprising one investor-owned utility, 41 electric membership corporations (EMCs), and 52 municipally-owned electric utilities. The PSC's full regulatory oversight for Georgia Power (the sole investor-owned utility) includes, but is not limited to: rate setting, financing application approvals, quality and distribution monitoring of power generating plants and environmental compliance plans, retail electric service transfer approvals, and determining resources to meet future electricity demand. The PSC maintains limited regulatory oversight of EMCs and municipal electric utilities, primarily focusing on retail electric service transfer approvals and deciding territorial complaints.

The Georgia Territorial Electric Service Act (Georgia, 1973), established in 1973 and administered by the PSC, allows retail customers with commercial loads of 900 kW or greater a one-time choice in their electric supplier. The Act also allows eligible customers to transfer from one electric supplier to another, provided all parties are in agreement. Georgia Power currently serves 155 of Georgia's 159 counties and does not provide service in Fannin, Union (location of the Blairsville Municipal Airport), Towns, and Crisp (location of the Crisp County-Cordele Airport) Counties.

Consistent with the Official Code of Georgia, Annotated (O.C.G.A.) Section 46-3A, each regulated electricity supplier in the State of Georgia whose rates are fixed by the PSC shall be required to develop an integrated resource plan and file it for review and approval. The plan outlines, among other things, the utility's 20-year forecast of energy sales and peak demand.

According to its 2022 Integrated Resource Plan (Power, 2022), filed with the PSC, Georgia Power forecasts robust economic growth for Georgia, citing the state's favorable business tax structure, lower cost of living, its globally connected transportation system (with the world's busiest airport and fastest growing port in the nation), and access to a workforce supported by its diverse university system. The plan notes that improvements in energy efficiency will drive some reductions in their forecast to account for increases in other areas, and it indicates there is sufficient supply to meet the current and forecasted demand for customers through the planning horizon from 2022 to 2041, as outlined in **Table 8-3** below. The annual energy demand in 2023 is forecast to be 84,522 Gigawatt hours (GWh) with a supply of 88,118 GWh. In 2041, energy demand is forecast to be 97,659 GWh with a supply of 101,813 GWh.

Table 8-3: Annual Electric Requirements & Supply in GWh

Year	Requirement	Supply
2023	84,522	88,118
2041	97,659	101,813

Source: (Power, 2022)

The State of Georgia does not currently have a renewable energy portfolio standard or mandate, but Georgia Power estimates that by the end of 2024, it will have deployed approximately 5,500 MW of renewable resources. This includes 480 MW of biomass and landfill gas, 250 MW of wind, and more than 4,700 MW of solar resources.

Estimated Cost for Airport Electric Charging Stations

On March 22, 2023, the Augusta Regional Airport completed the installation of the first electric aircraft charging station on a public-use airport in Georgia. The airside charging station supports fast charging up to 350 kW and is compatible with multiple eVTOL aircraft designs. The installation was a partnership between the airport commission, eVTOL and battery charger manufacturer BETA Technologies, and Georgia Power. The installation marks BETA Technologies' 10th charging location in the U.S., and they currently have an additional 50 installations underway along the East Coast.

As the eVTOL industry is in a nascent stage, there is an absence of publicly available information (either current or historical) regarding the costs of installing electric aircraft charging infrastructure. The expense of installing chargers at Augusta Regional Airport was not available for public release. To estimate the minimum required infrastructure and costs associated with placing two DC electric chargers—one airside, and one landside for surface vehicles—it was necessary to engage industry OEMs, vertiport developers, eVTOL battery charger manufacturers, and utility providers to determine their requirements and cost estimates.

The industry engagement yielded a consensus that a minimum of one megawatt of charging capability would be required. This would serve to future-proof the installation to support technological advancements in battery capabilities and support the rapid recharging currently required for electric aircraft.

The primary components of charging infrastructure include sufficient power delivered to an airport electrical panel, electrical cabling from the panel to charging sites, and the charger itself. Utility providers, such as Georgia Power, would be engaged to bring additional power to a panel at the airport to support the added capacity needs. The additional power would require a new transformer and panel. According to representatives from Georgia Power, orders for transformers currently have a 24-month lead time and panels have an approximately 12-month lead time. The cost to bring additional power to the airport is generally borne by the utility company and the cost recovered over time through its rate structure.

The remaining cost to install electric distribution cables from the panel to the charger and the cost of the charger would be borne by the airport, a third-party operator, or a combination of the two. The estimate for these two remaining cost components for one airfield and one landside charger, based on industry engagement, was between $500,000 and $750,000. The lower cost estimate of $500,000 was considered appropriate for smaller less congested general aviation airports where the length of the distribution cables from the panel to the charger was considered minimal. The higher end of the estimate was considered appropriate for larger general aviation airports and commercial service airports where it was assumed the distribution cables would need to be upsized to account for the longer distances required to reach the charger site(s).

Based on the PSCs Integrated Resource Plan prepared by Georgia Power there is forecasted to be sufficient supply of electricity in Georgia to meet projected demand through 2041. In the early stages of development, it is estimated that aircraft charging infrastructure for a single airport will cost between $500,000 and $750,000 to install two DC fast charging units – one airside and one landside predicated on the size and complexity of existing development on the airport. For the 10 airports in this study for which a detailed analysis was conducted to determine compatibility for the potential addition of eVTOL operations, it is estimated that approximately $6,750,000 would be required to install one airside and one landside DC fast charger and the associated infrastructure. Applying this estimate methodology, it is estimated that $57,250,000 will be required to install charging infrastructure at the 102 publicly owned public-use airports currently without a charger. These cost estimates are detailed in **Table 1-1** of the **GDOT AAM Study – Select Airports Analysis Report.**

In 2023, the National Renewable Energy Laboratory published the technical report titled "Impacts of Regional Air Mobility and Electrified Aircraft on Local Grid Infrastructure and Airport Electricity Demand (Cox, 2023)." The paper analyzed electrical infrastructure requirements that may be needed to service electric aircraft at a subset of airports that have sufficient demand. The paper covers a variety of assumptions, but it suggests the cost of equipment, materials, and installation of a Level 3 350kW charger would cost $684,850 and have a yearly operations and maintenance cost of $3,200. These assumptions are in line with the estimates derived from industry outreach in the prior paragraph.

Site-specific estimates for the infrastructure for electric aircraft charging will require the selection of a definitive location for the charger(s) and an accompanying set of electrical plans and specifications. Due to current supply chain issues affecting equipment delivery times airports interested in installing electric aircraft charging systems should be encouraged to engage with their utility provider as soon as practical to discuss the project; and complete a project planning process to identify the location of the charger consistent with FAA airfield design criteria; complete the project design and initiate the FAA 7460 process.

Georgia Power currently offers a competitive, application-based Make Ready Infrastructure Program that could potentially be utilized by airports to defray certain costs of installing electric chargers. The program requires that the chargers are available for public use like those in an airport parking area. Per the program guidelines, Georgia Power installs, owns, and maintains the electrical infrastructure behind the meter up to the charger. Georgia Power's ownership of the infrastructure would likely require an easement across airport property and an update of the airport's property map.

Strategically advancing electric aircraft charging infrastructure at airports will be a key factor in developing statewide and regional charging networks to support the evolution of the eVTOL aircraft industry and AAM. Recommendations from industry engagement which included OEMs, vertiport builders, utilities, and battery charging manufacturers indicated that airports should plan for the availability of a minimum of 1 megawatt of charging capability.

With an estimated two-year timeframe from concept to completion to install electric aircraft charging infrastructure, airports contemplating these projects should begin the process as soon as it is possible. The first step in this process is to engage with local utility providers and airport engineers to fully evaluate the appropriate location of charging infrastructure on their airport and then develop the necessary on-airport electrical plans to further refine cost estimates.

8.3 Synergies Between Airports and Alternative Fuel Corridors in Georgia

Alternative Fuel Corridors (AFC) were borne out of the 2015 Fixing America's Surface Transportation Act (FAST) in 2015 (Federal Highway Administration). This legislation "required the Secretary of Transportation to designate national electric vehicle (EV) charging, hydrogen, propane, and natural gas fueling corridors" (Federal Highway Administration, 2020). Since then, the Federal Highway Administration (FHWA) has embarked on a series of efforts to help fund, plan, and deploy these technologies. These efforts have been successful in installing electric vehicle charging infrastructure at strategic locations on our nation's major roadways including several in Georgia.

The AFCs are designated as either "Corridor-Ready" or "Corridor-Pending." Corridor-Ready indicates that "a sufficient number of facilities exist on the corridor to allow for corridor travel using one or more alternative fuels" (Federal Highway Administration, Alternative Fuel Corridor Convenings Final Summary Report, 2020). A Corridor-Pending designation indicates "an insufficient number of facilities currently exist on the corridor to allow for corridor travel using one or more alternative fuels" (Federal Highway Administration, Alternative Fuel Corridor Convenings Final Summary Report, 2020). For electric vehicles, the criteria for accommodating the above corridor readiness is an electric vehicle charging station at 50-mile intervals. For hydrogen fueling, it is a fueling facility at 100-mile intervals.

The program was established to develop a "robust network of alternative fuel corridors across the United States is critical for facilitating mid and long-range travel of commercial and passenger vehicles using clean-burning fuels, mitigating range anxiety, accelerating public interest and awareness of alternative fuel availability, and achieving substantial reductions in harmful vehicle emissions" (Federal Highway Administration, 2020). Since its inception, the corridor program has been updated annually with annual nominations sought for inclusion.

The cross-jurisdictional nature of highways necessitated an approach that provided structure and collaboration across states. The FHWA facilitated and convened a series of regional meetings in 2018 and 2019 to "encourage multi-state, multi-stakeholder regional coordination for the development and implementation of alternative fueling infrastructure along corridors. The convenings fostered an important opportunity for States to evaluate the potential of shared infrastructure investments and improved collaboration for education and outreach efforts between the public and private sectors" (Federal Highway Administration, 2020). The Southeast Region meeting took place in Charleston, South Carolina. The outreach and engagement effort provided significant insight into the challenges and solutions associated with developing infrastructure for new fuels.

Many of the FHWA findings in the AFC collaboration with other states may be relevant to the current efforts in aviation. Several observations emerged from the convening of states in the AFC effort most of which are directly applicable. The five primary observations centered on funding, regional coordination, value proposition, vehicle incentives, and addressing barriers (Federal Highway Administration, 2020).

Funding is always an issue and a challenge and one that will need to be addressed as new infrastructure is needed at airports. Making a business case and showing the value with respect to economic and environmental benefits will also be helpful. Lastly, addressing barriers to implementation is something the airport industry will need to do as many of these are the same on the surface vehicle front. This can include streamlining permitting processes, overcoming losses in revenue from fuel taxes, communicating benefits beyond cheaper conventional fuel, and making known and publicizing the availability of services at an airport.

With respect to funding, the initial AFC program did not come with a separate funding program. Instead, the FHWA program summary report refers to the availability of existing funding programs from several different governmental agencies to address funding needs. It was not until the Bipartisan Infrastructure Law (BIL) that funding was made available specifically for the AFC.

The law provided funds to further the "nationwide network of 500,000 EV chargers by 2030 that ensures a convenient, affordable, reliable, and equitable charging experience for all users" (Federal Aviation Administration, Building an Unleaded Future by 2030, 2023) . To that end, the BIL established the $5 billion National Electric Vehicle (NEVI) Formula Program which "will provide dedicated funding to States to strategically deploy EV charging infrastructure and establish an interconnected network to facilitate data collection, access, and reliability" (Transportation G. D.). This funding will initially be directed towards the AFCs building out the electric vehicle charging station network with an initial focus on the Interstate Highway System.

Subsequent to the AFC the funding can be used on other public roadways or for other publicly accessible facilities. BIL also created the $2.5 billion Charging and Fueling Infrastructure (CFI) Discretionary Grant Program (Federal Highway Administration, 2023). This program is available to local governments to "strategically deploy EV charging and other alternative vehicle-fueling infrastructure projects in publicly accessible locations in urban and rural communities, as well as along designated Alternative Fuel Corridors" (Federal Highway Administration, 2023). These funding programs provided for in BIL addressed, in part, one of the primary challenges identified in the corridor engagement efforts. And because of the increased availability of funding, the Corridor has received more attention among the states.

While the two programs mentioned above were created in BIL, other funding programs do exist to address the myriad other issues related to the transition to electric and alternative fuel infrastructure. **Figure 8-1** below shows the various programs currently available to address planning, construction, workforce, and other needs.

Figure 8-1: National Electric Vehicle Infrastructure (NEVI) Formula Programs

Construction and installation of EV charging infrastructure including parking facilities and utilities.	Workforce development and training related to EV infrastructure.	EV acquisitions and engine conversions - cars or trucks.	Planning for EV charging infrastructure and related projects.	Construction and installation of EV charging infrastructure to support operational, resiliency, national energy security, environmental, and community goals for freight transportation.	Installation of EV charging infrastructure as part of transit capital projects eligible under chapter 53 of title 49, United States Code.

	FY 2022[1] AMOUNT	EV charging infrastructure	Workforce development	EV acquisitions	Planning	Freight	Transit
FORMULA PROGRAMS							
National Highway Performance Program (NHPP)	$28.4 B[2]	✓	✓				✓
Surface Transportation Block Grant Program (STBG)	$12.5 B[2,3]	✓	✓		✓	✓	✓
Congestion Mitigation & Air Quality Improvement Program (CMAQ)	$2.5 B[2]	✓	✓	✓		✓	✓
National Highway Freight Program (NHFP)	$1.4 B[2]			✓	✓	✓	
State Planning and Research (SPR)	$983.3 M[4]				✓		
Metropolitan Planning (PL)	$438.1 M[2]				✓		
Carbon Reduction Program	$1.2 B[2,5]	✓	✓	✓	✓	✓	✓
National Electric Vehicle (NEVI) Formula Program	$685 M[2,5,6]	✓	✓		✓	✓	✓
DISCRETIONARY PROGRAMS							
Rebuilding American Infrastructure with Sustainability and Equity (RAISE) (formerly known as BUILD)	$1.5 B	✓			✓	✓	✓
Infrastructure for Rebuilding America (INFRA) Grant Program	$1.64 B[2,7]	✓			✓	✓	
Advanced Transportation and Technologies and Innovative Mobility Deployment	$60 M[2]	✓					✓
Discretionary Grant Program for Charging and Fueling Infrastructure	$300 M[2,5]	✓	✓		✓	✓	✓
Rural Surface Transportation Grant Program	$300 M[2,5]	✓	✓		✓	✓	✓
Reduction of Truck Emissions at Port Facilities Program	$80 M[2,5,7]	✓		✓		✓	
OTHER ALLOCATED PROGRAMS							
Federal Lands and Tribal Transportation Program (FLTTP)	$1.3 B[2,8]	✓	✓	✓	✓	✓	✓
Puerto Rico Highway Program (PRHP)	$173 M[2]	✓	✓	✓	✓	✓	✓
Territorial Highway Program (THP)	$46 M[2]	✓	✓		✓	✓	✓
INNOVATIVE FINANCE PROGRAMS							
State Infrastructure Banks (SIBs)	Varies	✓	✓	✓	✓	✓	✓
Transportation Infrastructure Financing and Innovation Act (TIFIA)	$250 M[2]	✓	✓	✓	✓	✓	✓

Source: Federal Highway Administration (Federal Highway Administration, Federal Funding is Available For electric Vehicle Charging Infrastructure On The National Highway System, 2022)

The NEVI Formula Program requires each state to submit an EV Infrastructure Deployment Plan annually. Georgia submitted its first plan in August 2022 that outlined its approach to using its $135 million (over five years) in apportionment money. The plan addresses a number of issues including internal GDOT coordination and coordination across other state agencies, stakeholder involvement and public outreach, the plan's vision and goals, various contracting models, and an analysis of existing and future conditions with respect to the state's land use patterns, the electrical industry and market (power providers), and state travel patterns.

The NEVI plan also addresses EV charging infrastructure deployment, more specifically the site selection process and various funding sources. The Georgia NEVI Deployment Plan discusses strategies for operations and maintenance, identifying service providers and station owners, and resilience and emergency evacuation among other issues. Equity considerations as well as those pertaining to labor and the workforce and cybersecurity are also addressed in the plan.

The plan notes that Georgia will focus deployment on existing and future AFCs, specific market segments such as freight and fleets, and end-user cases including charging stations. This will occur in coordination with local and regional stakeholders including border states. The criteria for NEVI-funded projects include:

- Open to the public or to authorized commercial vehicle operators from more than one company.
- Located first on Georgia's AFC network such that stations are installed.
- No more than 50 miles apart.
- Less than one mile from the AFC.
- Direct Current (DC) Fast Chargers with at least four Combined Charging System (CCS) ports capable of delivering a minimum of 150 kilowatts (kW) of power per port simultaneously for a total of at least 600 kW per station (Georgia Department of Transportation, Georgia Electric Vehicle Infrastructure Deployment Plan, 2022).

Figure 8-2 below shows a map of the designated corridors for electric vehicle charging in Georgia. There are currently no hydrogen corridors in the state. The designated corridors provide good connectivity between the urban centers of the state on major roadways as well as connectivity to neighboring states.

Figure 8-2: Alternative Fuel Corridors (Electric Charging) in Georgia

Source: Federal Highway Administration (Gael Le Bris, 2022)

Current Interstates in Georgia holding FHWA designations include (Federal Aviation Administration, 2023):

- I-16, I-20, I-75, I-85, I-95, I-185, I-575, I-985

Current US Routes or State Highways holding FHWA designations include (Federal Aviation Administration, 2023):

- SR-515, US-23, US-82, US-441

Opportunities exist that may provide some synergies between what is happening with electrical vehicles and infrastructure for surface transportation and what is developing in aviation. Airports can serve as locations for charging stations for both aircraft and surface vehicles. Bringing in the infrastructure to airports provides an opportunity to co-located automobile charging stations at the same time offering additional charging locations to the community.

Further, if an airport meets the AFC criteria, the charging stations at the airport can help further advance the AFC network. Additional work could be done to identify those airports that may currently meet the existing criteria as well as those that may in the future. Airports could help fill some of the charging location gaps that currently exist as well as build additional capacity to accommodate future growth in electric vehicles.

Since many smaller airports are in rural areas, charging stations at these airports could offer access to charging infrastructure to smaller, rural communities that have few or none. Electric aviation could serve as the impetus to increasing electric vehicle infrastructure in more rural or remote places. Additionally, as we see the emergence of hydrogen as a fuel, the same build-out approach we are seeing for electric vehicles is occurring or will occur with hydrogen.

Airports can play the same role as hydrogen-powered aircraft are already being currently developed and tested. Finally, there are some lessons that could be learned from the Georgia NEVI Deployment Plan that could be beneficial for aviation and airports. From the stakeholder and public outreach efforts to multijurisdictional governmental coordination, to workforce needs, power providers, and cybersecurity, many issues and stakeholders are the same.

8.4 Best Practices for Revenue Generation from Aircraft and Surface Vehicle Electrical Charging

Revenue Generation Models

Currently, a significant source of operating income for airports is derived from the revenue associated with the sale of jet fuel and avgas. As eVTOL aircraft enter the marketplace in the coming years, it will be important for airports to provision for the potential erosion of revenues from traditional aviation fuel sales that are likely to occur beyond 2030. Currently, this same issue, relative to electric automobiles, is impacting revenues for motor fuel which traditionally funds federal and state transportation trust funds, which are in turn used to construct, operate, and maintain surface transportation infrastructure.

In August 2022, GDOT released its Georgia NEVI Deployment Program which is a roadmap for the statewide deployment of a network of EV charging stations. The plan is derived from the 2021 Bipartisan Infrastructure Law enacted as the Infrastructure Investment and Jobs Act (IIJA) which provides approximately $5 billion nationally between FY2022 and FY2027 to advance a national network of EV charging stations. Georgia is slated to receive nearly $135 million to develop its portion of the national network. GDOT's NEVI Plan contains three revenue-generating models for electric vehicle charging which are consistent with industry published models. The three models as summarized in **Table 8-4** below are adapted from GDOT's NEVI Plan to apply to electric aircraft charging.

The three models consist of a Third-Party Owner-Operator Revenue Risk model, a Facilitator Revenue Risk model, and a Hybrid Revenue Risk model. In the Third-Party Owner-Operator Revenue Risk model a third party owns, operates, and maintains the equipment; sets the pricing; and controls the overall customer experience. This business model would typically appeal to third parties with established aircraft charging services and software. This model is viewed as attractive to airports interested in hosting chargers as a customer service but is not interested in investing capital or operating and maintaining the systems themselves. Under this model, the third-party owner-operators would enter into a ground lease and pay an agreed-upon amount to the airport for the lease.

In a Facilitator Revenue-Risk model, the airport incurs all the costs of installation, operations, and maintenance of the charging facility. All revenue is attributed solely to the airport. This model can appeal to airports that desire to own the charging systems and control the revenue generated.

The Hybrid Revenue Risk model would typically be negotiated on a case-by-case basis to best match the needs of both the airport and third-party owner-operators, which could include fixed-based operators. In some cases, an electric aircraft charging equipment supplier could own and operate the chargers and offer revenue-sharing opportunities to the airport to incentivize them. Or airports could negotiate fees to generate revenue based on the volume of electricity sold. This could be considered equivalent to fuel flowage fees currently charged by some airports.

Table 8-4: Electric Aircraft Charging Business Models and Risk

Third-Party Owner-Operator Revenue Risk	Facilitator Revenue Risk	Hybrid Revenue Risk
In a Third-Party Owner-Operator Revenue-Risk model, a third party owns, operates, and maintains the equipment. The owner-operator would set pricing and control the overall customer experience. This business model typically appeals to third parties with established aircraft charging services and software. This model is also viewed as attractive to airports interested in hosting chargers as a customer service but is not interested in investing capital or operating and maintaining the systems themselves. Under this model, the third-party owner-operators would enter into a ground lease and pay an agreed-upon rent to the airport.	In a Facilitator Revenue-Risk model, the airport incurs all the costs of installation, operations, and maintenance of the charging facility. All revenue is attributed solely to the airport. This model can appeal to airports that desire to own the charging systems and control the revenue generated.	There can be multiple variations of a Hybrid Revenue-Risk model through which airports and third-party owner-operators can engage. Some electric aircraft charging equipment suppliers will own and operate chargers but offer revenue-sharing opportunities to incentivize airports to install the charging infrastructure. Other options can include fixed-term service plans, where a third party owns and operates the system for an agreed-upon term and the airport then has an option, at the end of the term, to purchase the system. Hybrid solutions would typically be negotiated on a case-by-case basis to best match the needs of both the airport and third parties.

Airports, if feasible, should consider locating charging infrastructure in proximity to FBOs, terminals, and restaurants. Pilots and passengers waiting for their aircraft to charge would have access to other amenities that could drive additional revenue opportunities.

Statutory Considerations

As previously mentioned above, the prevalence of electric automobiles is impacting motor fuel tax revenues that states and the federal government use to fund the construction, operation, and maintenance of surface transportation infrastructure. To address this issue in Georgia, during its 2023 session, the Georgia General Assembly passed Senate Bill 146 and its companion House Bill 406 authorizing the resale of electricity by the kilowatt hour for electric vehicles and the collection of a motor fuel excise tax on the sale and use of certain electricity and hydrogen. The bills and their resulting statutes also remove the provision of electricity to propel motor vehicles through an electric vehicle charging station from the regulatory authority of the PSC and provides regulatory authority to the state's Department of Agriculture over electric vehicle charging stations including operating standards, licensing, and inspections. The bills do not change the current $211 annual fee paid by the owners of small battery-powered cars and the $317 annual fee charged to the owners of commercial electric vehicles. Prior to this bill, the sale of electricity for electric vehicles was limited to charges based on time to charge.

The provision of the bill relating to the excise tax on motor fuel is not effective until January 1, 2025, and expands the definition of motor fuel to include electric and hydrogen. The excise tax defines the one-gallon equivalent for electricity as a motor fuel at not more than 11 kilowatt-hours. The statute currently restricts the excise tax to motor fuels designated for vehicles on public highways. In order for the state to impose this excise tax on electric aircraft charging the statutory definition of motor fuel would need to be amended to include the use for aviation.

The bill prohibits local governments or other political subdivisions of the state from levying any fee, license, or other excise tax on the sale, purchase, storage, use, consumption, or other disposition of motor fuel. However, it explicitly does not prohibit local governments and political subdivisions from levying licensing fees or taxes upon any business selling motor fuel.

Federal Requirements Regarding Airport Revenues

Airports should ensure that any revenues generated from electric aircraft charging are appropriately expended on the airport consistent with FAA Airport Improvement Program Grant Assurance No. 25-Airport Revenues. This grant assurance requires that all revenues generated by the airport and any local taxes on aviation fuel established after December 30, 1987, be expended by the airport for the capital and operating expenses of the airport.

Electric Charging Fees

According to Mach One Roadside Assistance, the average charging cost per kilowatt hour for DC fast charging for electric vehicles is between $0.40 and $0.60. The prices differ based on factors including the EV charging level, the type of charger, and the location of the charger depending on time-of-day demand. Additionally, Tesla offers a four-tiered pricing strategy based on the time to charge in minutes. The lowest price per minute Tier 1 cost is for charging at or below 60 kW with the highest price per minute is for charging above 180 kW. There is currently no publicly available data to evaluate the retail price charged to electric aircraft, as chargers that are in operation are used to support the testing operations of private companies.

Revenue-generating models for electric aircraft charging include third-party owner-operator revenue risk, facilitator revenue risk, and hybrid revenue risk. These models provide airports options to install, own, and operate the charging infrastructure, contract with third parties, or develop hybrid variations of these models to provide revenue to the airport. Statutory changes in Georgia, beginning in January 2025, allow for the retail sale of electricity by the kilowatt hour and the provision of an approximately $0.312 per 11 kilowatts excise tax on the sale of electricity as a motor fuel for highway use. The statutory changes for the levy of an excise tax on electricity would need to be modified in order for them to provide revenue at the state level associated with electric aircraft charging.

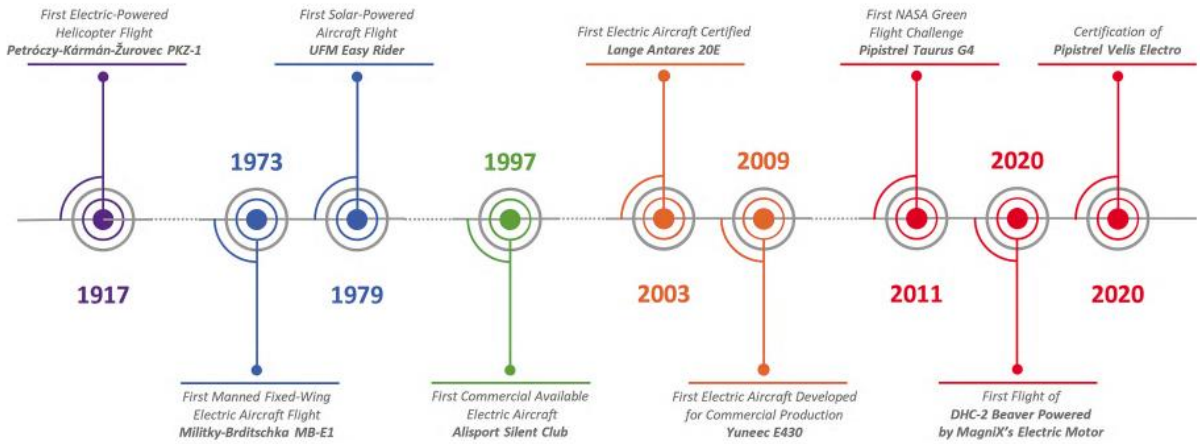
8.5 Alternative Aviation Fuel Technologies

The last several years have seen significant advances in how aircraft are powered. Most readily visible is the progress made towards electric aviation and Sustainable Aviation Fuels (SAF). There are a number of aircraft manufacturers designing and building electric aircraft with significant investment and partnerships coming both from within the aviation industry as well as outside from technology companies and automobile manufacturers. Advances have also been made in alternative fuels for conventional aircraft both to remove lead from aviation gasoline and provide more sustainable options for jet fuel. These are commonly known as SAFs—biofuels that are safe, reliable, and low carbon. The most work on SAFs is occurring in the commercial airline sector where fuel cost, environmental, and energy security challenges present major issues. Collectively, these fuel technologies provide opportunities for a more sustainable aviation industry that includes both quieter aircraft and fewer emissions.

Electric and Hydrogen Aviation Technologies

While much has been written about electric aircraft in the last few years, it is not entirely new. The first attempt at electric aviation dates back to 1917 and the development of an electric-powered helicopter that flew three people (Le Bris, 2022). The endeavor was scrapped after three flights, and it would be more than 50 years before it picked up again. Efforts, however, began in earnest in the last 15 years and really grew in the last five years. **Figure 8-3** below provides a timeline of electric-powered aviation.

Figure 8-3: Timeline of the Emergence of Electric Aviation, 1917-2020



Source: Preparing Your Airport for Electric Aircraft and Hydrogen Technologies (Le Bris, 2022)

Previous chapters outlined the emergence of eVTOL aircraft, some of which are predicted to be certified and begin commercial operations in 2025 and 2026. The predominant use cases that are expected to take place have been identified and airports across the country have begun installing electric charging infrastructure. The level of investment and the depth of the partnerships indicate electric aircraft are expected to become mainstream. Charging networks for aviation are already being built out including in Georgia (BETA Technologies, 2023). As the technology develops, particularly with respect to battery life, larger aircraft are expected to become certified and operational.

While electric aviation propulsion system continues to evolve, hydrogen too is emerging as a potential aviation power source. Hydrogen, in large part, has become of interest because it is abundant and produces low emissions. Hydrogen has the advantage of having high energy density compared to its weight—approximately 1kg of hydrogen equates to that found in 3kg of jet fuel in energy produced (Le Bris, 2022). But as with electric aviation, hydrogen-powered aviation will need its own set of guidance and standards for its safe storage, handling, and operations. Significant research is currently underway on hydrogen-powered aviation including the development of hydrogen-powered aircraft and efforts to develop standards and infrastructure. As with electric-powered aircraft, there have been previous attempts to power aircraft with hydrogen, with the first dating back to the 1950s (Evers, Baldwin, Black, & Pettitt, 2023). Hydrogen can be used as a fuel source in different ways including in conjunction with an electric motor where hydrogen is used to generate electricity.

The FAA has been funding hydrogen research for many years, including through the Center of Excellence for Alternative Jet Fuels and Environment, which is sponsoring research on hydrogen propulsion technologies (Federal Aviation Administration). The FAA has also worked with the National Renewable Energy Laboratory on research for both electric and hydrogen-related projects (National Renewable Energy Laboratory).

The private sector is also working on hydrogen technologies for aviation. Three of the leading companies involved in developing hydrogen technologies include Airbus, Universal Hydrogen, and ZeroAvia. The latter two have recently reached milestones in the development of hydrogen-powered aircraft.

Airbus is developing hydrogen fuel cells, hydrogen combustion, and hybrid engines. Their ZEROe aircraft is a hybrid of hydrogen and traditional combustion engines, and they have partnered with engine manufacturer CFM to outfit an Airbus A380 for testing. Airbus believes hydrogen is a promising fuel for aviation given its energy-per-unit mass, and as such, they plan to "develop the world's first hydrogen-powered commercial aircraft by 2035" (Airbus, 2023). Airbus sees two primary uses for hydrogen: 1) hydrogen propulsion where hydrogen is used in a modified gas-turbine engine or converted into electrical power that complements the gas turbine, and 2) synthetic fuels where hydrogen can be used to create "e-fuels," which are generated exclusively through renewable energy (Airbus, 2023). **Table 8-5** below depicts Airbus' range of hydrogen-powered concept aircraft and their capabilities.

Table 8-5: Airbus ZEROe Concept Aircraft

Aircraft Type	Passengers	Power System	Range
Turbo Prop	< 100	Hydrogen; Hydrogen Turboprop	1,000+ nm
Blended-Wing Body	<200	Hydrogen; Hydrogen Turbofan	2,000+ nm
Turbofan	<200	Hydrogen; Hydrogen Turbofan	2,000+ nm

Source: Airbus (Airbus, 2023)

Universal Hydrogen, a California-based company founded in 2020, has a mission to decarbonize aviation. It is backed by a plethora of financial and strategic investors across the technology and financial spectrum including Airbus Ventures, GE Aviation, Toyota Ventures, American Airlines, Jet Blue Technology Ventures, and Mitsubishi HC Capital (Universal Hydrogen). In February 2023, the company announced it had received an experimental airworthiness certificate that allowed it to conduct the first flight of its hydrogen-powered aircraft—a de Havilland Dash 8-300 with one of its engines replaced with a hydrogen fuel cell electric powertrain (Welsh, 2023).

The aircraft made its first debut in early March 2023 from Moses Lake, Washington with a 15-minute flight that reached an altitude of 3,500 ft. (Weitering, 2023). The company is also developing conversion kits for the ATR 72-600 airliner and expects those to be certified and in commercial service in 2025 (Welsh, 2023). Additionally, it is developing and testing a modular delivery system at its Toulouse, France engineering center. The company's chief executive officer has stated that Universal Hydrogen is "simultaneously providing a pragmatic, near-term solution for hydrogen infrastructure and delivery, as well as for converting existing passenger aircraft to use this lightweight, safe, and true-zero-emissions fuel" (Welsh, 2023). The company has received a preorder for 75 converted aircraft from Connect Airlines (a Massachusetts-based regional airline) as well as an agreement with Avmax Aircraft Leasing to convert 20 of its existing aircraft to hydrogen power (Weitering, 2023).

Six weeks before Universal Hydrogen's flight, the United Kingdom-based ZeroAvia, founded in 2017, made the first flight of a hydrogen-powered aircraft. The company partnered with Alaska Airlines to retrofit a Bombardier Q400 with a hydrogen-electric propulsion engine. "ZeroAvia's hydrogen-electric engine uses fuel cells to generate electricity from hydrogen fuel before using that electricity to power electric motors, which turn the aircraft propellers" (Emir, 2023). Additional partners to ZeroAvia include Textron and Shell.

ZeroAvia has established a timeline for the development of commercial passenger aircraft development (see **Table 8-6** below). Some experts believe the timelines are aggressive given the testing and regulatory approvals that will be necessary.

Table 8-6: ZeroAvia Passenger Aircraft Development Timeline

Year	2025	2027	2029	2032	2040
Seats	9-19	40-80	100-200	200	200+
Range	300 NM	1,000 NM	2,000 NM	3,000 NM	5,000 NM

Source: CNBC (ZEROAVIA)

Other potential barriers that have been noted include the onboard space required for hydrogen systems. This may preclude use on larger aircraft, focusing viability on the small and medium-sized fleet. Additionally, the infrastructure and supply chains will need to be built to accommodate the new systems (Evers, Baldwin, Black, & Pettitt, 2023). There is research underway on all of these fronts for what many consider a viable long-term solution to reducing carbon emissions in aviation and building more efficient and sustainable systems.

The Vertical Flight Society has been actively involved in the area of hydrogen-powered aviation and published a whitepaper entitled *Multimodal Hydrogen Airport Hub*. Published in late 2022 and updated in March 2023, the "whitepaper proposes gaining consensus and agreement on safety, developing common fueling infrastructure, interfaces, storage technology and scalability of hydrogen solutions in aerospace" (Vertical Flight Society, 2022, p. 4). It "takes the first step at harmonizing and aligning onboard aircraft hydrogen storage by type, quantity, and acceptable fill times" (Vertical Flight Society, 2022, p. 4). Significant resources are being deployed both in the public and private sectors to develop hydrogen alternatives for aviation. "However, no adequate infrastructure today delivers large quantities of hydrogen from the production sites to the aircraft" (Le Bris, 2022).

The current success demonstrated by these three companies, and others, in such a short period of time suggests hydrogen is promising for the future. New research continues daily examining hydrogen's use in aviation including the infrastructure needs associated with hydrogen-powered aircraft. While it is still early to make capital decisions regarding hydrogen infrastructure, airport sponsors and state aviation offices should continue to monitor development in hydrogen technologies recognizing that planning for alternative fuels will be an ongoing process to ensure airports have the ability to meet the needs of aircraft in the future.

Charging Station Standardization

While the aviation industry has yet to settle on a standard for electric aircraft charging, lessons can be learned from a similar transition to electric vehicles in the automobile industry. However, it should be recognized that aircraft are very different than automobiles in that they will require more power and present some challenges with respect to parking and charging on a ramp given their wingspans and the presence of other aircraft. The needed power will also require "thicker, longer, and heavier charging cables, perhaps integrated cooling systems for MW capability, high voltage to the site, and the ability to bank power on site from both the grid and on-site generation from sources such as solar" (Huber, 2023).

SAE International is currently working to establish such a standard through the Aircraft Energy Storage and Charging sub-committee (AE-7D), which is part of the Aerospace Electrical Power and Equipment Technical Committee (AE-7) (SAE International, 2019). The standard will pertain to the "technical requirements related to the design and minimum performance requirements of connection set of conductive charging systems used for charging electrically powered aircraft" and is referred to as the "connection set of conductive charging for light electric aircraft (AS6968)" (SAE International, 2019). This charging standard is intended for the "sub-500kW power class", which are essentially smaller, lighter aircraft (Electro.Aero). Another standard is also being developed for larger aircraft—AIR7357 MegaWatt and Extreme Fast Charging for Aircraft. "The proposed AIR will detail power levels required for future electric aircraft applications and detail design considerations and use cases for megawatt and extreme fast charging for electric aircraft. The AIR will provide a mapping to other industry standards that may have relevance as well as detail areas where technology gaps/future design considerations will need to be addressed" (SAE International, 2020).

Electro, a manufacturer of aircraft chargers based in Australia, and its chief technology officer Josh Portlock, were instrumental in founding the SAE International AE-7D sub-committee (Marquand, 2023). The work necessary in this industry going forward can be summarized by Portlock:

> "There's more than half a dozen different DC fast-charging standards in the world. . . . Now that's fine if you are a Tesla [electric car] and you're building millions of cars, have hundreds of engineers, and can cater to all those different standards when you ship your cars around the world; but not so much when you're a low-volume aircraft manufacturer with an international market. You want that same aircraft to be able to charge with the same standard anywhere in the world. As [eVTOL] aircraft range gets longer, you want to be able to fly between regions, between countries, without having to use adapters and carry additional charging hardware with you" (Huber, 2023).

Electro is developing chargers in the 30-80 kW range that are compatible with the standard noted above. They are also working to develop larger chargers in the 200-400 kW range but note that such chargers will be dependent on the electric power that is available at the airport or vertiport (Huber, 2023). While little has been made publicly available about the charging equipment used by the myriad of OEMs currently developing aircraft, the current thinking "includes eschewing AC/DC charging converters on the aircraft or AC couplers on power plugs in favor of wheeled, portable, DC fast chargers with dual ports that can be easily moved by one person up to the aircraft" (Huber, 2023).

The real limiting factor for electric aircraft could be the ability of the airport to supply the needed power. Existing wiring in many of the hangars in use today has an upper limit of 40 kW (Marquand, 2023). As for many of the electric aircraft and eVTOLS that are anticipated before the end of the decade, "a typical four-seat electric aircraft requires 80kw-200kw of charging and an eVTOL of similar size requires as much as 400kw" (Marquand, 2023).

Through its work on the SAE committee, the industry is working to standardize charging equipment knowing the difficulties the automotive industry faced with the "chaos of the EV industry in which there are about two or three couplers competing in each country. It is already challenging for large automotive manufacturers to cater for all six couplers globally and would be considerably more difficult for an electric aircraft OEM with a small team" (Marquand, 2023). The six charging couplers worldwide today include AS6968, AIR7357, CCS1, CCS2, China's ChaoJi (CHAdeMO 3.0), and Tesla's North American 1kV (Marquand, 2023). **Figure 8-4** below, although from the U.S. Department of Energy's resources on electric vehicles, provides some insight and clarity into the charging needs and solutions in aviation vis-à-vis these six charging couplers.

The figure below also shows which charging equipment is associated with the various charging levels along with the associated power needs of the vehicle and the charging times. It also illustrates the challenges associated with interoperability when multiple standards and options exist. But as noted previously, the charging needs of electric aircraft are significantly higher than surface vehicles, placing more of a focus on the related infrastructure to get the power needed onto the airport or vertiport.

Figure 8-4: Electric Vehicle Charging Equipment

Level 1 Charging

Approximately 5 miles of range per 1 hour of charging*

J1772 connector

Alternating Current (AC) Level 1 equipment (often referred to simply as Level 1) provides charging through a 120 volt (V) AC plug. Most, if not all, EVs will come with a portable Level 1 cordset, so no additional charging equipment is required. On one end of the cord is a standard NEMA connector (for example, a NEMA 5-15, which is a common three-prong household plug), and on the other end is an SAE J1772 standard connector (often referred to simply as J1772, shown in the above image). The J1772 connector plugs into the car's J1772 charge port, and the NEMA connector plugs into a standard NEMA wall outlet. Note that Tesla vehicles have a unique connector. All Tesla vehicles come with a J1772 adapter, which allows them to use non-Tesla charging equipment.

Level 1 charging is typically used when there is only a 120 V outlet available, such as while charging at home, but can easily provide charging for most of a driver's needs. For example, 8 hours of charging at 120 V can replenish about 40 miles of electric range for a mid-size EV. As of 2021, less than 2% of public EVSE ports in the United States were Level 1.

* Assumes 1.9 kW charging power

Level 2 Charging

Approximately 25 miles of range per 1 hour of charging†

J1772 connector | Tesla connector

AC Level 2 equipment (often referred to simply as Level 2) offers charging through 240 V (typical in residential applications) or 208 V (typical in commercial applications) electrical service. Most homes have 240 V service available, and because Level 2 equipment can charge a typical EV battery overnight, EV owners commonly install it for home charging. Level 2 equipment is also commonly used for public and workplace charging. This charging option can operate at up to 80 amperes (Amp) and 19.2 kW. However, most residential Level 2 equipment operates at lower power. Many of these units operate at up to 30 Amps, delivering 7.2 kW of power. These units require a dedicated 40-Amp circuit to comply with the National Electric Code requirements in Article 625. As of 2021, over 80% of public EVSE ports in the United States were Level 2.

Level 2 charging equipment uses the same J1772 connector that Level 1 equipment uses. All commercially available EVs in the United States have the ability to charge using Level 1 and Level 2 charging equipment.

Tesla vehicles have a unique connector that works for all their charging options, including their Level 2 Destination Chargers and chargers for home. All Tesla vehicles come with a J1772 adapter, which allows them to use non-Tesla charging equipment.

† Assumes 6.6 kW charging power

DC Fast Charging

Approximately 100 to 200+ miles of range per 30 minutes of charging‡

CCS connector | CHAdeMO connector | Tesla connector

Direct-current (DC) fast charging equipment (typically a three-phase AC input) enables rapid charging along heavy traffic corridors at installed stations. As of 2021, over 15% of public EVSE ports in the United States were DC fast chargers. DC fast charging is projected to increase due to fleets adopting medium- and heavy-duty EVs (e.g., commercial trucks and vans and transit), as well as the installation of fast charging hubs for transportation network companies (e.g., Uber and Lyft) and other applications.

There are three types of DC fast charging systems, depending on the type of charge port on the vehicle: SAE Combined Charging System (CCS), CHAdeMO, and Tesla.

The **CCS** connector (also known as SAE J1772 combo) is unique because a driver can use the same charge port when charging with AC Level 1, Level 2, or DC fast charging equipment. The only difference is that the DC fast charging connector has two additional bottom pins. Most EV models entering the market today can charge using the CCS connector.

The **CHAdeMO** connector is another common DC fast connector type.

Tesla vehicles have a unique connector that works for all their charging levels including their fast charging option, called a Supercharger. Although Tesla vehicles do not have a CHAdeMO charge port and do not come with a CHAdeMO adapter, Tesla does sell an adapter.

‡ Charging power varies by vehicle and battery state of charge.

Source: U.S. Department of Energy (U.S. Department of Energy; Energy Efficiency and Renewable Energy, 2023)

The recently published ACRP Report *Preparing Your Airport for Electric Aircraft and Hydrogen Technologies* provides detailed information on what airports need when it comes to electric and hydrogen aircraft technologies. Both are very different in terms of infrastructure and operational needs. When it comes to electricity, the authors note that "airport planners must consider the power requirement, location, funding, and ownership of these charging facilities" (Le Bris, 2022). Recharging of aircraft can take different forms. The airport could have fixed or mobile chargers and/or batteries that could be swapped. **Table 8-7** below shows the pros and cons of the various charging methods. Researchers recommend that aircraft manufacturers work towards a unified standard whether it is a current one or entirely new.

Table 8-7: Electric Aircraft Demand Conclusions

Charging Method	Pros	Cons
Battery Swapping	• Currently faster layover times meet a better operational case for aircraft. • Peak power needed could be lower. • Possibly more effective for seaplanes.	• Increased maintenance risks. • Possible damage to aircraft during • swapping. • Infrastructure may require more space. • Legal questions on battery ownership when swapping batteries at different airports. • Currently lacks FAA support.
CCS/Standardized	• Known standard already vetted with ground electrical vehicles. • Equipment more readily available and cost-effective. • Backward compatible with future technologies.	• Limited by standards to <400 kW charging speeds. • High power charging may have a tougher impact on the grid. • Depends on acceptance of this standard by manufacturers and use case.
Charging	• Customized per aircraft to suit specific needs. • Could be faster to market or allow for different charging profiles with specific battery technologies	• Not standardized so different aircraft may not use the same charger. • May cause operational issues as the industry adapts to multiple proprietary methods.

Source: ACRP Report 236 (Le Bris, 2022)

Likewise, for hydrogen, airports may ultimately have container swapping, fueling trucks, or a hydrant system to refuel hydrogen aircraft. Since hydrogen is in its initial stage of development for use as an energy source in aircraft, the amount needed, fuel tank capacities, and methods of fueling are not yet clearly defined (Le Bris, 2022). **Table 8-8** below summarizes the recharging and refueling technologies for electric and hydrogen aircraft. As a point of reference, airport terminals typically consume more than half an airport's electricity (Le Bris, 2022, p. 26). The remaining is used on the airfield. This could change significantly with the emergence of electric aircraft.

Table 8-8: Recharge and Refuel Technologies

Ramp Integration	Batteries	Fuel Cells
Fixed Airport Units	Electric Chargers	Hydrant System
Mobile Airport Units	Superchargers on Truck or Trailer	Tanker (Truck)
Swap of Energy Containers	Battery Swap	Container Swap

Source: ACRP Report 236 (Le Bris, 2022)

Table 8-9 from ACRP Report 236, provides insight on the power needs of various types of electric aircraft. It should be noted that as part of this report, researchers developed an assessment tool to help airports better understand their electricity demand due to the growth of electric aircraft.

Table 8-9: Power Requirements Per Number of Aircraft Charging Simultaneously (Le Bris, 2022)

Mission	Baseline Aircraft	Capacity	Power Requirements (Assuming 45 Minutes Recharge)				
			1	5	10	20	50
Flight Training, Private, Recreational	Pipistrel Alpha Electro	1 pilot + 1 passenger	20 kW	100 kW	200 kW	400 kW	1 MW
Very Short Range (420 miles)	Short range (700 miles)	1 pilot + 3 passengers	60 kW	300 kW	600 kW	1.2 MW	3 MW
Short Range (650 miles)	Eviation Alice	2 pilots + 9 passengers	400 kW	2 MW	4 MW	8 MW	20 MW
Short Range (700 miles)	UTC Project 804	2 pilots + 39 passengers	600kW	3 MW	6 MW	12 MW	30 MW

Source: ACRP Report 236 (Le Bris, 2022)

As the industry evolves, standards develop, and more becomes known about the charging protocols from the electric aircraft and eVTOL manufacturers, airports and others in the industry will be able to make more informed decisions. FBOs may also be able to help make the transition as some have already committed to adopting the technology needed by the electric aviation industry (Alcock, 2021).

Sustainable Aviation Fuels and Replacements for 100LL

Two fuel-related challenges that have permeated aviation in recent years pertain to the fuels used by both general aviation piston aircraft and turbine-powered aircraft. For piston aircraft, the primary fuel has been 100LL, which is the last remaining commercially available leaded fuel. Different initiatives have been undertaken over the years to find alternatives to leaded fuel. The Piston Engine Fuels Initiative (PAFI) began in 2014 with the intention of helping to evaluate potential replacement fuels for 100LL. Once identified, fuels would then be tested by the FAA collaboratively with the industry. In February of 2022, the FAA, in conjunction with industry partners, launched the Eliminate Aviation Gasoline Lead Emissions (EAGLE) initiative with the goal of eliminating leaded fuel in aviation. This FAA public-private partnership seeks to do so by the end of 2030 (Federal Aviation Administration, 2023). The earlier PAFI program was then integrated into the EAGLE initiative and remains the part of the program where new fuels developed by industry are evaluated and tested by the FAA.

The initiative's focus is on the following:

"Identify at least one unleaded fuel acceptable for safe General Aviation fleet use.

1. Minimize the safety and technical impacts associated with high-performance engines using unleaded fuels.
2. Facilitate the increased production, distribution, and greater use of unleaded replacement fuels.
3. Ensure that 100 low-lead fuel is available during the transition to unleaded fuel.
4. Establish policies that support airport infrastructure funding for unleaded fuel.
5. Endorse plans that reduce or eliminate reliance upon leaded aviation fuels" (Federal Aviation Administration, 2023).

The EAGLE initiative's path can be seen in **Figure 8-5** below.

Figure 8-5: EAGLE Initiative Path to Lead-Free Fuel

Source: Federal Aviation Administration (Federal Aviation Administration, 2023)

These initiatives have led to the development of 100LL alternatives including approval for the fleetwide certification of General Aviation Modifications' (GAMI) G100UL fuel as an unleaded alternative for 100LL (Scarbrough, 2023). A conversion to G100UL will not require separate tanks and can be stored in the same tanks as 100LL. Supplemental Type Certificates (STC) for G100UL are currently available (General Aviation Modifications). The fuel itself is expected to be available in 2024 as 2023 will be a year of logistical adjustment. "Although the FAA signed off on G100UL in September, the initial rollout of the fuel won't begin until later this year—starting with California.

GAMI anticipates all West Coast states to roll out the fuel by 2024, with national availability by 2026" (Walsh, 2023). Flight schools will likely be among the first to get the fuel before wider distribution. GAMI is working with Avfuel for commercial distribution and is the first to receive fleet-wide FAA approval (Avfuel, 2023). While the fuel has been documented as being safe for engines, others, including builders, still need to make sure it is safe for other components of the fuel system including seals and tanks (Niles, 2023). Additional information on the fuel's development, testing, distribution, and availability can be found at https://www.avfuel.com/Fuel/Alternative-Fuels/Unleaded-Avgas.

Philips 66 and Afton Chemical are also working on an alternative to 100LL called UL100 with a commercialization date anticipated in 2025 or 2026 which is still in development (Philips 66, 2018). Additionally, Swift Fuels has developed an alternative called UL94. It has been produced and sold since 2015 and is drop-in ready requiring no modifications or changes. However, UL94 may not be suited for all piston aircraft and pilots should check with Swift to determine which aircraft can use this fuel.

SAF typically refers to a replacement fuel turbine aircraft, particularly the commercial jet fleet. As with other alternative fuel sources, SAFs have been the subject of significant government and industry research. SAFs can be made from a variety of sources and have the potential to significantly reduce greenhouse gas emissions.

A recent U.S. General Accountability Office (GAO) report on the SAFs identified the following:

- "SAF is alternative jet fuel made from renewable and waste feedstocks that can reduce greenhouse gas emissions on a lifecycle basis.
- SAF production and use in the U.S. has increased in recent years; this fuel is now used by airlines at two major commercial airports in California.
- While U.S. production reached 15.8 million gallons in 2022, it accounted for less than 0.1 percent of the total jet fuel used by major U.S. airlines. This also falls well below the previous Federal Aviation Administration goal for U.S. airlines to use 1 billion gallons of SAF per year by 2018" (U.S. General Accountabiilty Office, 2023).

Progress has been made on the alternative fuels front both in terms of a replacement for 100LL Avgas and the use of more sustainable replacements for the commercial fleet. Timelines for 100LL replacement have been better established with one fleet-wide alternative already approved and in use. The timeline for SAFs replacing jet fuel is more uncertain. The White House, to reduce greenhouse emissions associated with aviation, issued a "Grand Challenge" with the goal of producing three billion gallons of sustainable jet fuel per year by 2030 and enough to meet 100% of commercial jet fuel demand by 2050 (U.S. General Accountabiilty Office, 2023).

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