MID-ATLANTIC AVIATION PARTNERSHIP
VIRGINIA TECH™

REPORT

Analysis of Minimum Viable Infrastructure (MVI) to Support Advanced Aerial Mobility (AAM) Operations Across the Commonwealth of Virginia

v2.0

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Executive Summary

We are on the edge of a fundamental shift in how aviation shapes the movement of people and cargo. The concept of Advanced Air Mobility (AAM) captures a vision for aviation that is nimble, ubiquitous, and powered by autonomy, encompassing everything from ten-pound drones carrying three-pound packages across town to helicopter-sized autonomous aircraft ferrying commuters between urban centers.

A report published last year by NEXA Capital projected that AAM could add more than $12 billion to Virginia's GDP over the next two decades and create more than 17,000 jobs — compelling estimates that nevertheless capture only a subset of potential applications. These economic gains will be supplemented by substantial social benefits. State agencies can respond more quickly to emergencies; public safety officers can approach volatile situations with greater situational awareness; residents in remote areas of the Commonwealth will have better access to the state's most advanced hospitals.

Reaching a stage where engagement with aviation will become almost as routine as engagement with ground transportation will require substantial work in domains including regulation, technology development and validation, standards development and validation, and community outreach. All of those efforts require substantial investment at the federal, state, and local level. This report proposes a set of targeted, strategic investments for the Commonwealth of Virginia.

The recommendations outlined below and detailed in the following pages are oriented around the concept of a *Minimum Viable Infrastructure* (MVI): A network of components that is distributed, flexible, and adaptable to the unique needs of particular environments. This comprehensive backbone will attract future projects, leveraging a lean initial investment to anchor a diverse, collaborative and self-sustaining ecosystem for development, testing, validation, and deployment.

This report will make the case for an MVI model guided by these principles:

- The highest returns will flow from investments in sensors and data sharing network infrastructure.
- These infrastructure components should primarily support two types of initiatives: (1) Active pilot program operations, and (2) Research and validation activities in well-equipped test ranges.
- Mutually beneficial public-private partnerships, supplementing Commonwealth funds with investment by equipment providers and champion operators, will yield the most stable funding streams.
- All infrastructure investments should be linked to a viable business model.

That overall strategy will be supplemented with specific recommendations, including

- Establish detect and avoid services at strategically selected existing test sites using proven ground-based systems.
- Preferentially establish pilot programs in areas protected by mandated ADS-B equipage.

- Enable pilot programs for smaller-scale operations by utilizing cost-effective acoustic detection and medium range radar systems, which are efficient when networked.
- Identify and establish public-private partnerships with manufacturers of small UAS to support pilot programs, and with companies focused on larger vehicles to support the equipage of advanced testbeds.

Challenges facing AAM implementation

Federal aviation regulations, designed around traditional crewed aircraft, have struggled to adapt to new modes of aviation. The most significant hurdles are related to the challenges of routinely permitting flights beyond the visual line of sight — a requirement for economic viability for most applications but one that demands a technological alternative to the crewed pilot's ability to see and avoid other aircraft. There are also significant regulatory challenges in aircraft certification, particularly in regards to certifying autonomous systems.

Technology development is where these regulatory barriers intersect with state-level investment. Solutions for sensing, quiet propulsion, security, traffic management, communications, navigation, and other functions are all being developed to address the unique challenges presented by AAM. These technologies must demonstrate that they can ensure an acceptable level of safety and community acceptance before their use can be codified in federal regulations, and new regulations provide a target to design against. States can play a role in advancing regulation by supporting technology development and validation.

States must also engage with communities to better understand how innovation can be deployed to create the greatest societal benefits, and to ensure that the public understands the technology and is receptive to it. The FAA's AAM Implementation Plan[1] emphasizes the importance of proactive community engagement at the local and regional levels, beginning in the planning stages of new projects.

All of this work requires substantial investment: In test facilities, human and intellectual capital, in infrastructure, in public outreach, and in networks of expertise. As the movement to modernize aviation gathers momentum, and both large and small companies invest heavily in technology and use case development, states and municipalities willing to make those investments have the opportunity to shape the next generation of aviation and ensure that their citizens are first in line for its benefits.

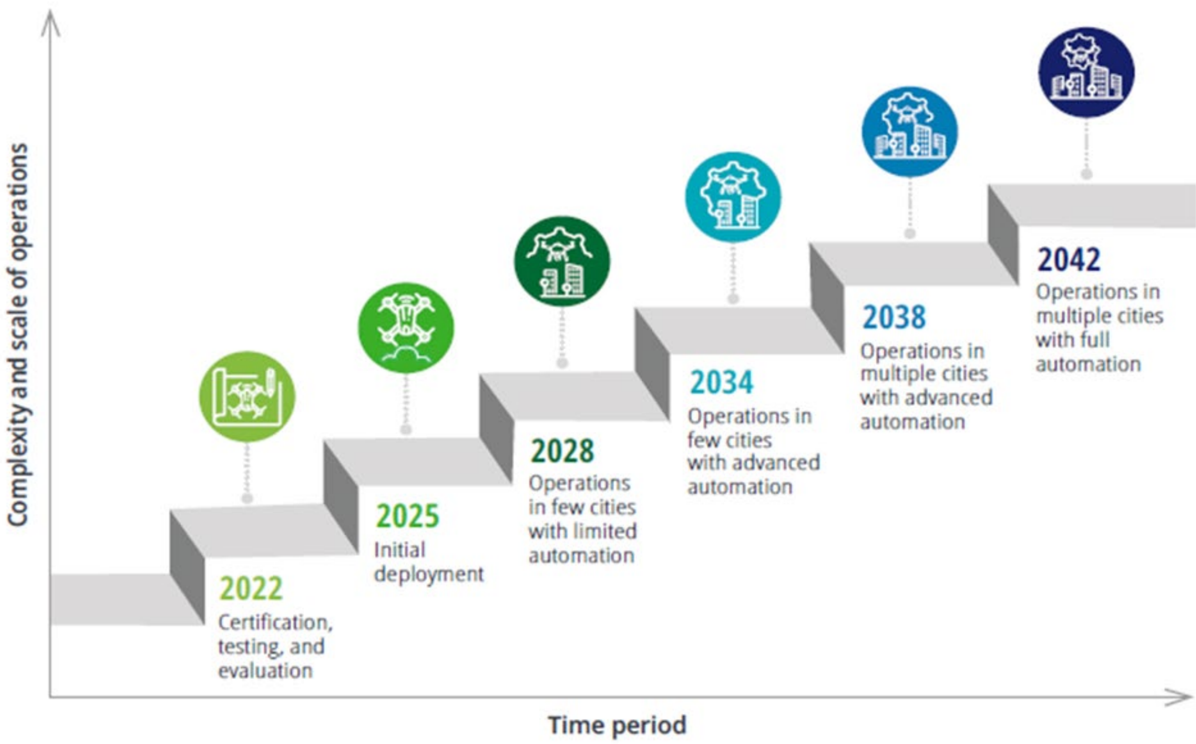
Other states have already invested aggressively in AAM infrastructure. New York, Ohio, and North Dakota have all stood up well-equipped test ranges that have attracted business investment; Michigan recently appropriated substantial funding for similar projects. Virginia has long been a fertile and productive environment for science and technology, and is home to multiple active research and commercial projects in AAM. However, the Commonwealth has not yet made a concerted effort to invest in the necessary infrastructure at scale and in a coordinated way. Now is

[1] https://www.faa.gov/air-taxis/implementation-plan

an opportune time to make those investments, and secure a leadership position for Virginia in this growing sector.

An MVI approach for Virginia

Investing strategically in a careful mix of projects can yield meaningful benefits in the short term and position the state competitively to become a hub for this industry as it develops over the next decades.



Expected AAM adoption timeline consisting of six phases spanning the next 20 years. Source: Deloitte https://www2.deloitte.com/us/en/insights/industry/aerospace-defense/advanced-air-mobility.html

For the deployed operations, we have identified four near-term use cases. All of these focus on applications for small uncrewed aircraft systems (sUAS). The fully-fledged vision of AAM includes airframes on the scale of today's small crewed aircraft. However, for the next five to ten years the majority of real-world integration of AAM concepts will happen on smaller systems.

These sUAS will be the proving ground for the technologies and regulations that will ultimately enable the full suite of AAM use cases. Many of the technologies essential to safely integrating these smaller systems — methods for detecting and avoiding other aircraft, reliable and secure long-range communications, strategies for traffic management — are prerequisites for a robust AAM ecosystem. Getting these systems right for smaller airframes, which present lower risks both for other airspace occupants and to people on property on the ground, will lay a solid foundation for more ambitious operations with more advanced systems.

The four use cases profiled in this report, and suggested strategies for implementation, are (1) Drones as first responders in densely populated urban areas; (2) medical deliveries in remote rural communities; (3) on-demand emergency response leveraging a statewide network of fixed and mobile assets that would enable rapid, targeted responses; and (4) commercial drone deliveries serving consumers in metros with large suburban areas.

For each use case, the report provides a roadmap for implementation, including recommendations for MVI, factors that will influence safety case development, economic models, and relevant state and federal regulations. Encouraging the adoption of these use cases in a deliberate, systematic manner will yield meaningful benefits for communities in Virginia. In the meantime, data from these operations — not only on technical performance but also on economic and social benefits and public acceptance — will inform future technology and use case development.

As detailed in the report, appropriate infrastructure for these pilot programs should include ground-based detect and avoid systems to provide airspace surveillance. Candidate technologies for this purpose include lower cost acoustic and radar systems which, when deployed as a network, can provide the coverage necessary to support operations in areas where a reasonable value proposition can be realized.

There are also opportunities to leverage existing assets to enable these programs. For example, there are four areas in Virginia where ADS-B out is required for crewed aircraft. These mandate areas pave the way for expedited approvals by minimizing noncooperative traffic and reducing the obligation to install systems to detect it. The population centers that coincide with these areas are therefore excellent candidates for pilot programs, particularly (1) and (4).

While those operations are generating real-world insights about the value of AAM in practice, complementary investments in diverse, well-equipped test ranges will establish and widen a strategic industry pipeline.

Virginia already has an impressive array of environments that serve formally or informally as test ranges for sUAS research and testing. The Virginia Tech Mid-Atlantic Aviation Partnership, officially designated by the FAA as a UAS test site, offers permissions (including for testing aircraft up to 1320 lbs.) and facilities that can support a range of research activities and has a long track record of enabling industry firsts. In Hampton Roads, the confluence of a busy port, general aviation airport, urban environment, and nearby NASA facility creates numerous opportunities for research integrating next-generation autonomous systems into existing transportation infrastructure. The controlled airport at Blackstone already hosts uncrewed test operations along with its regular crewed traffic, supports both military and civilian operations, leverages use of a restricted airspace, and also has the first official vertiport designation in the U.S. It is ideally situated to test strategies for integrating low-altitude traffic with traditional controlled traffic. Other military installations also offer protected airspace that could potentially support advanced testing not permitted or advisable in open airspace. Test ranges operated by MITRE and the NASA Langley Research Center present additional possibilities. Supplementing the resources already available in these environments with thoughtfully selected infrastructure will attract AAM companies seeking well-equipped test and validation environments.

Crucially, these facilities span a range of key environmental characteristics including varied geographies and population densities. When considering MVI for AAM research, it is advantageous to distribute investments across diverse environments to increase the likelihood of a match between sponsors' research needs and test range capabilities. For example, rural areas, where low population density reduces ground risk, are ideal for research with larger, heavier airframes and the ideal proving ground for middle-mile applications like regional air mobility. In contrast, urban areas present an opportunity to evaluate technology in a more physically and electromagnetically complex environment and test applications that will ultimately be deployed in those landscapes — urban air mobility, for example.

The report will outline recommendations for MVI that can augment existing infrastructure to make those diverse environments even more valuable as test ranges.

Again, the primary equipment recommended in the report is detect and avoid technology. One important role of the test ranges will be to support testing for larger aircraft, which will have the advantage of being able to support onboard sensors for this purpose. Most of these vehicles will be optionally piloted in the early stages of deployment, allowing the pilot to continue to fulfill that role; however, those onboard systems must be validated to allow the industry to progress towards full autonomy. Proven ground-based detection systems will be an essential validation tool.

It will be especially productive to combine these high-performance sensors with a supplemental data service provider to feed sensor data into an associated traffic management platform. This infrastructure will allow aircraft manufacturers and operators to demonstrate that their system can meet an acceptable level of safety when coupled with appropriate ancillary technologies, and companies producing sensors and software to demonstrate that their systems can ensure these safety standards are met. This is particularly valuable as the FAA moves from a model of approving individual operations in their entirety on a case-by-case basis to a more efficient templating approach in which new applicants can expedite approvals by leveraging systems already approved in similar operations. Systems integrated into high-performance test ranges and thus utilized in operational approvals have the potential to quickly build a significant footprint in the industry — an incentive that can be very valuable in encouraging investment by these companies.

Eventually, these technologies can be supplemented by additional infrastructure such as vertiports and hangars to facilitate advanced testing and early commercial implementation of larger aircraft – potentially including regional air mobility services between the Washington, D.C. metro area and other Virginia population centers. This combination of assets will establish Virginia as a leader in AAM and create a pathway for future investment.

The Future of AAM

The majority of this report focuses on MVI supporting near-term sUAS use cases as the "crawl" stage in an overall AAM crawl-walk-run strategy that will capitalize on near-term approvals and use cases while building industry momentum and regulatory and public buy-in.

The near future (next 3-5 years) of larger AAM/UAM aircraft operations will largely follow traditional aviation practices and procedures while introducing electric STOL/VTOL aircraft[2].

[2] https://ntrs.nasa.gov/api/citations/20230002647/downloads/NASA-TM-20230002647_Final.pdf

These aircraft will initially include a pilot on board with a commercial license, flying aircraft certified with modified Part 21 procedures and utilize existing rules, with an infrastructure for airborne operations that includes existing charted routes and ATC services. Additionally, due to the relatively limited range of most AAM aircraft as compared to traditional aircraft, instrument approaches for sequencing aircraft will need to be developed that are tailored for shorter approaches into airports.

Near to mid-term requirements for UAM operations may include the development of Vertiport/Vertistop facilities and charging/servicing infrastructure either by modifying existing helipad locations or creation of new dedicated on or off-airport facilities, including AAM/UAM specific approach procedures to these off-airport sites[3].

As the industry moves into more autonomous operations and/or simplified aircraft controls (5+ years from now) changes in regulations and procedures will be required. New pilot certifications may be needed for remotely piloted or optionally piloted aircraft, and new certification methods for aircraft will be needed as they become more autonomous and methods of control become more simplified, such as single button takeoff and land functionality. It is envisioned that more autonomy will give way to self- separation through private-industry defined strategic deconfliction services, and as such dedicated AAM/UAM operating areas and corridors will need to be created that separate more autonomous AAM traffic from traditional air traffic.

In addition to laying the initial AAM strategy groundwork through sUAS infrastructure and use case implementation, recommendations for enabling near-term AAM/UAM operations include:

1. Establish public/private partnerships that incentivize OEM's through investment in on and off airport infrastructure that accelerates technology and regulatory development.
2. Leverage Virginia based FAA Test Sites and programs as a conduit for FAA involvement and to provide accelerated pathways and added value to OEM collaboration and investment
3. Invest in vertiport development with accompanying instrument approaches at test and evaluation locations in order to encourage aircraft manufacturers to establish test and validation operations and aircraft manufacturing in Virginia.
4. Work with eVTOL manufacturers and operators to determine locations in VA that best fit their business model
5. Perform community outreach and education in these areas to gauge buy-in
6. Work with airports in these identified locations to develop vertiports and charging/maintenance facilities
7. Work with applicable stakeholders to develop AAM vehicle specific approach procedures for the selected vertiport locations
8. Continue building momentum and operational tempo by expanding operational locations across the state within the current regulatory framework

[3]https://www.faa.gov/sites/faa.gov/files/2022-08/UTM_ConOps_v2.pdf

For mid to long-term AAM/UAM operations

1. Encourage State-Level involvement in applicable public and private AAA industry working groups
2. Monitor near-term operations for lessons learned and integrate w/ future plans

In Closing

The key to an effective MVI strategy, either for test and validation or for deployed operations, is a set of strong public-private partnerships where multiple organizations pool their resources to enable mutually beneficial projects. Every state investment under a Commonwealth AAM MVI initiative should be complemented by private investments from equipment providers, champion operators, or both. Incentivizing these investments will require that every project undertaken as part of this initiative should have a clear link between research activities or pilot operations and a viable business model. One advantage Virginia has in attracting these partnerships is its proximity to federal lawmakers and regulators, facilitating technology demonstrations and other interactions that can raise partners' visibility and help advance their regulatory and legislative goals.

When seeking promising collaborations, Virginia can rely on the many organizations already working in those space, who can leverage their existing partnership networks to understand industry needs and identify appropriate test plans and validation environments. One additional strategy for forging solutions-oriented public-private partnerships is a competitive grant program that would supplement industry investment with matching state funds.

The targeted, strategic investments outlined in this report can create an infrastructure that will become a magnet for external investment and a nexus of research and development. Virginia has an opportunity to create a self-sustaining hub of AAM activity that will capitalize on the Commonwealth's potential to lead the next generation of aviation and realize the potential of this technology to benefit society.

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Document Change Record

Date	Document Version	Section Impacted	Revision Description
Nov. 2023	1.0	Baseline Document	
Jan. 2024	2.0	Throughout	Expanded document to address larger AAM definitions and use cases
		Executive Summary	Expanded summary to include additional AAM timeframes and recommendations
		2.0	Added section discussing overall AAM definitions and regulatory guidance
		2.4	Added information detailing the differences between small and large AAM requirements
		3.2.4	Included additional State-Level AAM initiative examples
		16.0	Added section providing overview of potential near-term AAM use cases
		17.2	Expanded recommendations to include AAM/UAM

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1.0 Introduction

Advanced Aerial Mobility (AAM) will leverage advancements in aviation to enable new methods of work and efficient transportation of goods, cargo, and people, offering societal and economic benefits beyond what has been possible with traditional methods and transportation alone. The aircraft that will enable this transformation will range from small uncrewed aircraft systems (sUAS) for use cases like inspections and deliveries to crewed and, eventually, uncrewed electric vertical takeoff and landing (eVTOL) aircraft for use cases like Urban and Regional Air Mobility that will connect people and services in ways never before possible.

AAM operations will require a network of physical and digital infrastructure that maximizes capabilities, benefits, and safety. The scale and scope of this effort is beyond the capacity of the FAA. For the Commonwealth to foster and capitalize on this new industry, there must be public/private partnerships that can develop and deploy cost-effective solutions that enable near-term services and lay the groundwork for long-term, sustainable return on investment. These investments must be scalable, repeatable, and economically viable to provide the public with the widest range of services and benefits while enabling business models that attract early adopters and investors in this emerging industry.

This report explores a Minimum Viable Infrastructure (MVI) model that will enable AAM across the Commonwealth in a way that allows needed infrastructure to be scaled appropriately for the area, use case, and business model it is intended to support. The infrastructure discussed will be designed primarily to support sUAS use cases; this is the segment of AAM with the greatest potential for near-term implementation, and the core technologies for these use cases will also be foundational for larger airframes in the future. The report will examine various use cases, using examples to illustrate how they may best serve the needs of the Commonwealth, accompanied by region-specific recommendations to accommodate the state's diverse geography and regional demand signals.

The report will also discuss technologies which can support an acceptable level of safety for airspace used by both autonomous and traditional crewed aircraft will be explored. Potential business models and considerations for return on investment will also be addressed. Methods of practical implementation, including Local, State, and Federal buy-in and approvals, regulatory, considerations, and industry standards relevant to proposed investments in MVI will also be discussed, along with projections for how these projects may affect policy and regulation at the state and federal level.

Additionally, two near to mid-term AAM/UAM use cases will be highlighted as recommendations for a follow-up study of larger AAM missions. These use cases include UAS cargo delivery using autonomous heavy lift UAS, as well as piloted UAM operations for movement of people.

Finally, the report will offer concrete recommendations for next steps that can begin to lay the groundwork for implementing AAM across the Commonwealth.

2.0 Advanced Air Mobility

Advanced Air Mobility (AAM) refers to a transportation system using highly automated electric aircraft or electric vertical take-off and landing aircraft, operating in both controlled and uncontrolled airspace to move people and cargo between places more efficiently, especially in currently underserved local, regional, urban, and rural areas. In addition to novel propulsion systems, advancements would also introduce various levels of autonomy as systems mature, including simplified on-board pilot controls, remotely piloted options, and full autonomous operations for piloting, navigation, and traffic separation. Several subsets exist under the overall AAM umbrella, including Urban Air Mobility (UAM) for operations centered around transporting people within a specific geographical location such as a city, Regional Air Mobility (RAM) for operations that transport people to various locations within a defined region, Large Cargo delivery, which differs from drone package delivery in both size and scope of operations, and other small UAS use cases for public benefit.

2.1 The Advanced Air Mobility Coordination and Leadership Act

The Advanced Air Mobility Coordination and Leadership Act (H.R. 1339) was introduced to the House by the U.S. Department of Transportation and NASA in November of 2021, and was written into Public Law (No. 117-203) on October 17, 2022. This law directs the Department of Transportation to establish an Advanced Air Mobility (AAM) interagency working group to plan for and coordinate efforts to integrate AAM aircraft into the national airspace system, including efforts related to safety, operations, infrastructure, physical security and cybersecurity, and Federal investment necessary for maturation of the AAM ecosystem in the United States, particularly passenger-carrying aircraft, in order to:

(1) grow new transportation options;

(2) amplify economic activity and jobs;

(3) advance environmental sustainability and new technologies; and

(4) support emergency preparedness and competitiveness.

2.2 NASA AAM Vision

NASA proposed a vision for an ecosystem of connected technologies working together within an AAM and UAM framework (Figure 1). UAM is a smaller subset of AAM in that it will be focused on a smaller, more specific geographical region, whereas AAM would interconnect multiple UAM areas, as well as support longer range flights outside of urban areas. This AAM vision steps through a logical progression of UAM Maturity Levels (UML) ranging from initial operations (UML-2) in low density areas with low-complexity operations using assistive automation all the way through an end-state (UML-4) consisting of fully automated systems operating medium density and medium complexity operations. Examples of each UML may be:

UML-2:	UML-3:	UML-4:
Cargo Delivery	Air Ambulance	On-Demand Air Taxi
Airport Transfer	Inter-City Operations	
Cross-Metro transfer		
Medical Transfer		

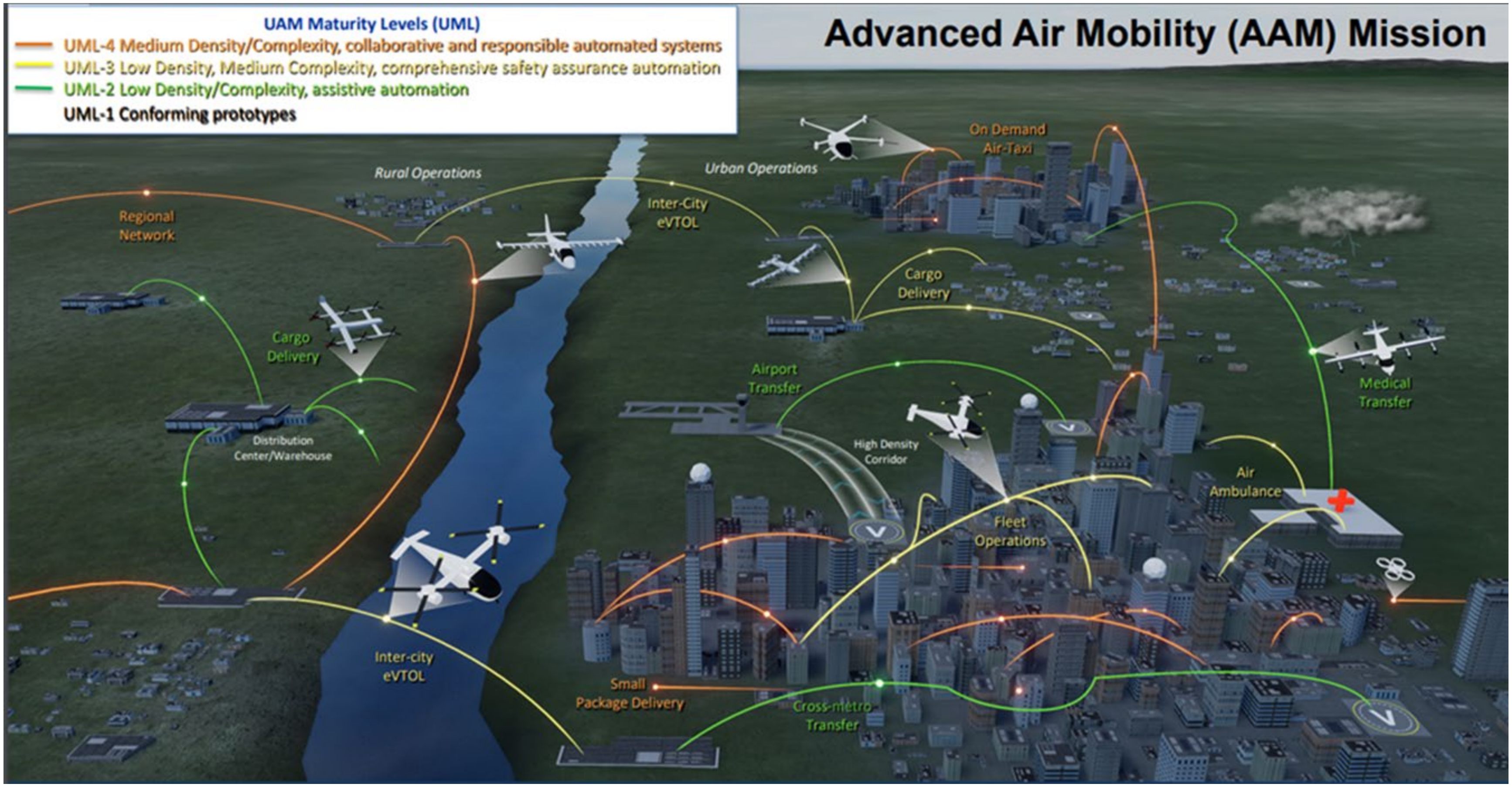


Figure 1: NASA vision for an AAM concept incorporating UAM into a larger ecosystem of connected technologies and processes. Source: NASA Advanced Air Mobility Mission. https://www.faa.gov/sites/faa.gov/files/media/airports/2021/march/airports-mar2021-NASAAdvancedAirMobility(AAM)Mission.pdf

2.3 FAA AAM/UAM Guidance

The FAA has released two documents related to AAM: Urban Air Mobility (UAM) Concept of Operations Version 2.0[4], and Advanced Air Mobility Implementation Plan Version 1.0[5]. The UAM ConOps focuses on a technical roadmap for enabling UAM, or urban-focused subsets of AAM, while the AAM Implementation Plan focuses on documenting the work required for enabling initial overall AAM operations in the near-term

UAM ConOps

The FAA's UAM ConOps document is a comprehensive outline for enabling UAM operations from a regulatory standpoint. One of the main concepts described in this document is the operating environments these types of operations may occur in, specifically the air traffic management aspect of separating these aircraft from each other and from existing air traffic. Initially, low-tempo UAM operations may leverage current regulatory frameworks such as Visual (VFR) and Instrument (IFR) flight rules, however as operations become more frequent and complex, new cooperative operating environments known as Extensible Traffic Management (xTM), will be required to complement traditional Air Traffic Services (ATS) for future passenger or cargo-carrying operations/flights (Figure 2).

The FAA has proposed three distinct operational evolutionary stages that define the required enabling mechanisms based on operational tempo, aircraft automation level, and location of the pilot.

Initial UAM operations will have a low operational tempo and utilize aircraft that are consistent with current aircraft technologies, including having a pilot on-board. These operations will be supported by existing rules, procedures, and routes, with operations requiring additional accommodation addressed by Letters of Agreement (LOA) or other existing mechanisms.

Midterm UAM operations may still have a low operational tempo but are pushing the boundaries of what existing environments and regulations can support. Aircraft and automation will be more advanced with the introduction of Remote Pilots and simplified pilot interfaces. UAM corridors may be established to separate UAM aircraft from traditional air traffic in areas known as Cooperative Areas (CA), which would require cooperative management by users, thus introducing the xTM concept via a performance-based airspace structure. This new operating environment may utilize 3rd party Suppliers with FAA oversight to implement cooperative separation and flow management via procedures/practices that allow users to directly exchange operational intent information with each other and the FAA for deconfliction.

Mature UAM operations are defined as higher tempo with more advanced aircraft, leading to full autonomy. This level of UAM operations would require extensive regulatory and airspace management changes that would incorporate lessons learned and technology advances from Initial and Midterm operations.

[4]https://www.faa.gov/sites/faa.gov/files/Urban%20Air%20Mobility%20%28UAM%29%20Concept%20of%20Operations%202.0_0.pdf

[5] https://www.faa.gov/sites/faa.gov/files/AAM-I28-Implementation-Plan.pdf

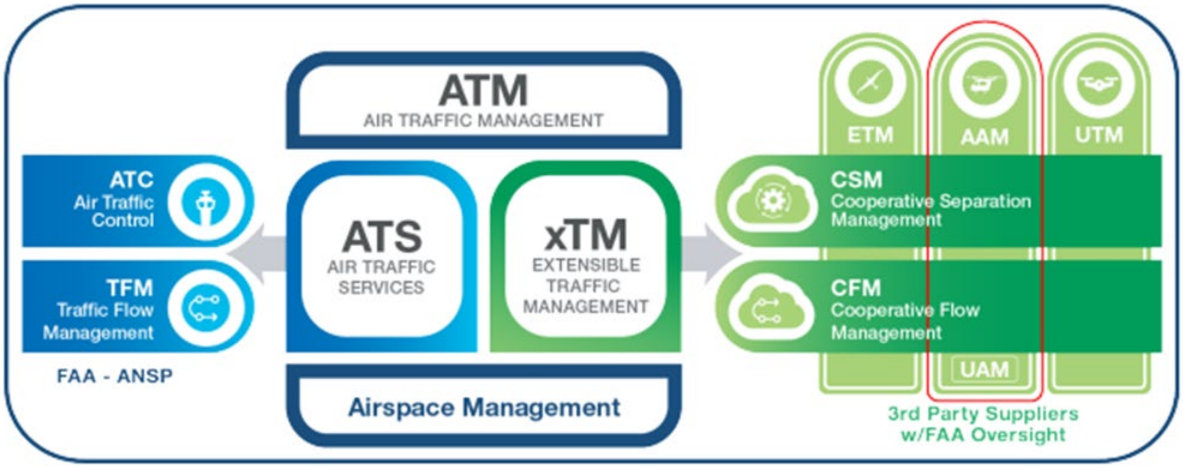


Figure 2: FAA notional overview of AAM/UAM air traffic management utilizing 3rd party services. Source: FAA Urban Air Mobility Concept of Operations 2.0
https://www.faa.gov/sites/faa.gov/files/Urban%20Air%20Mobility%20%28UAM%29%20Concept%20of%20Operations%202.0_0.pdf

Advanced Air Mobility Implementation Plan

In July of 2023, the FAA released their near-term AAM Implementation Plan for integrating AAM operations into select key sites the NAS by 2028, titled "Innovate28". This plan largely follows their UAM ConOps document for near-term implementation, and reiterates several key initial integration points:

1. Initial airspace usage, routes, will be roughly the same as currently used by traditional aviation. This includes utilizing charted routes as the primary route structure for AAM operations as defined in 14 CFR Parts 91 and 135.

2. Air Traffic Control services will be provided to AAM aircraft as needed or required in accordance with current rules and regulations, with no major changes in services or automation planned for the near term.

3. Infrastructure required to support AAM operations will primarily consist of existing airport and heliport facilities with some modification to account for AAM specific needs such as charging facilities, dedicated parking/loading/unloading zones, and adequate fire management systems and procedures specific to electric propulsion. New vertiport facilities would follow FAA guidance found in Engineering Bulletin 105 for vertiport design, with federally obligated facilities following rules contained in 14 CFR Part 77.9 and 14 CFR Part 157 for non-federally obligated facilities or development of new off-airport facilities.

4. Airmen certification and standard/suggested safety practices for operation of AAM aircraft may be modified through existing mechanisms, including but not limited to Advisory Circulars, Review Boards, FAA Technical Orders, and other standard publications or methods.

2.4 Differences Between sUAS and Larger AAM Requirements

AAM encompasses a variety of electric aircraft executing use cases with increasing levels of autonomy that span from small, sub 55 lb. UAS for operations such as drone as a first responder (DFR), and medical delivery, all the way through passenger-carrying aircraft transporting people between cities. The regulatory pathways and required infrastructure are currently scaled to meet both operational demand and technological capability, with future implementation for expansion derived from FAA planning documents as mentioned above. This section aims to resolve the key differences between regulatory approval pathways, required infrastructure, and traffic management across these differing AAM use case areas.

2.4.1 Regulatory Approvals

Small UAS Operations

The regulatory authority for the safe operation of small UAS (sUAS) is derived from 14 CFR Part 107, which limits operations to aircraft weighing under 55lbs. Part 107 allows for operators to apply for waivers for certain provisions, given adequate safety case information is provided to the FAA that demonstrates how the operator will mitigate risk to an acceptable level. For sUAS that engage in package delivery and includes Beyond Visual Line of Sight (BVLOS) operations, Part 135 certification is required. Pilot certification for operation using sUAS is regulated under Part 107.12.

Large UAS Operations

Large UAS operation may derive operational authority from US Code Chapter 448, which grants authority over certain uncrewed aircraft systems, Section 44806 for Public operations directs the Secretary of Transportation to streamline and expedite the process for the issuance of a certificate of authorization or a certificate of waiver and provide guidance on a public agency's responsibilities when operating an unmanned aircraft without a civil airworthiness certificate issued by the Administration. Additionally, 44807 allows the Secretary of Transportation to use a risk-based approach to determine if certain uncrewed aircraft systems may operate safely in the national airspace system without an airworthiness or type certificate. Authority for certifying aircraft for sage operation in the NAS may also come from 14 CFR Part 21.17(b), where UAS are considered a special, nonconventional class of aircraft and the FAA has authority to apply portions of other airworthiness requirements that are relevant to these new type aircraft. Large UAS that will carry goods for hire may also be subject to Part 135. Pilot certification may be regulated under Part 61 and Part 135, dependent on operational specifics.

Passenger Operations

Currently, passenger operations will fall under Part 91 operating and flight rules, as well as Part 135 for the carriage of passengers. Aircraft certification will fall under 14 CFR Part 21.17(b) where the FAA has authority to apply any applicable sections of the certification process, as well as create new processes for novel aircraft designs. Pilot certification will be regulated under Part 61. As aircraft become more automated, regulations will need to be modified or newly created to accommodate both aircraft and pilot certification.

2.4.2 Infrastructure

Takeoff and Landing Facilities

sUAS may take off and land from any area that is deemed safe from collision with people or property, and typically includes a small portable landing pad for simple operations. More structured facilities may be developed for larger-scale operations such as high-volume package delivery. These accommodations are traditionally developed by individual operators and may not be considered traditional infrastructure components that feed into a system as a whole, but rather enable a single operation.

Figure 3:Examples of sUAS take off and landing accommodations appropriate for the scale of operations considered, including a simple portable landing pad (left) and dedicated facilities (right).

Larger UAS Cargo delivery aircraft, depending on configuration, may use existing airport facilities or create dedicated, secure takeoff and landing areas at key logistics sites such as ports, railyards, and warehouse facilities. These sites may be areas cordoned off from non-participating people and include landing pads, cargo loading and unloading zones, and charging capabilities.

Passenger carrying aircraft will require more extensive infrastructure such as on or off airport vertiports for takeoff and landing, passenger management, charging, and maintenance. The FAA has provided guidance on vertiport design in Engineering Brief #105[6], Vertiports may be incorporated into an existing airport layout and operations plan or may be created at off-airport locations that are advantageous to passenger movement such as on top of buildings or parking garages and near bus or train stations.

[6] https://www.faa.gov/sites/faa.gov/files/eb-105-vertiports.pdf

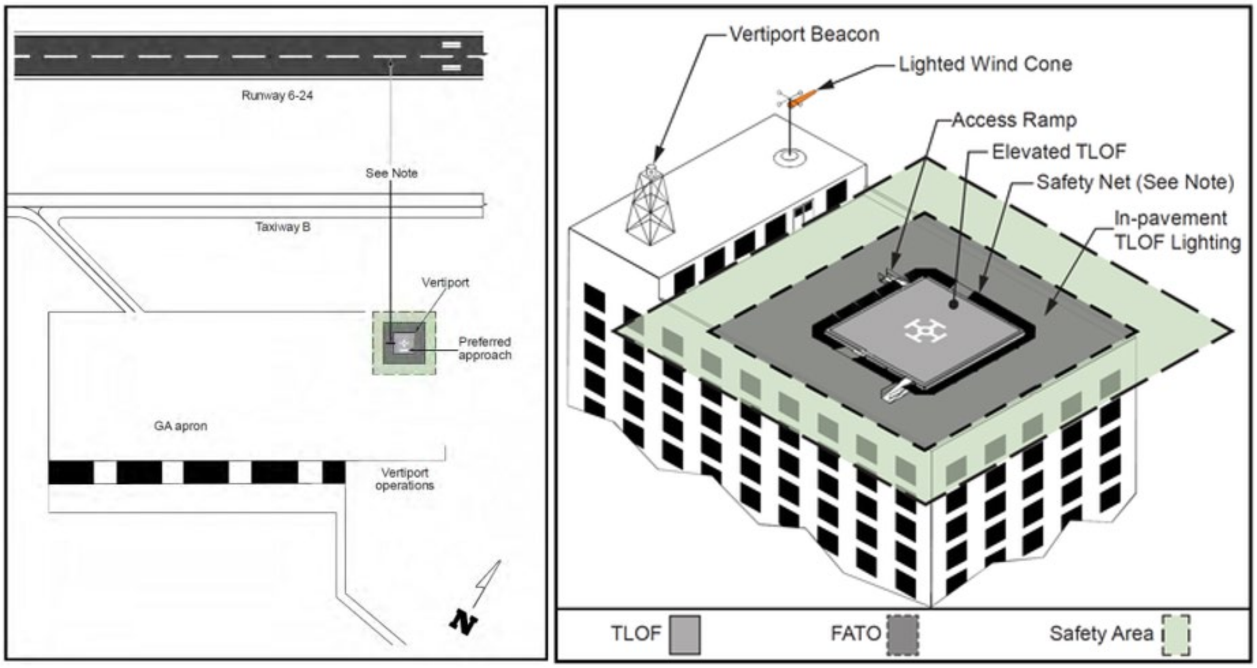


Figure 4: Examples of FAA guidance on creation of on-airport (left) and off-airport (right) vertiports.

Communications

Traditionally, uncrewed aircraft conducting localized, smaller-scale operations have utilized ISM band frequencies for pilot to UAS radio links, which are unlicensed and therefore subject to interference and other security concerns. As use cases transition to operations involving BVLOS flight, a secure method of communications will be required to establish the command and control link between aircraft and pilot to ensure integrity of link in the event of emergency. One-off solutions such as individual aircraft LTE or SATCOM radios may facilitate specific operations, however larger scale commercial or public operations that operate over a larger geographical area or with a larger fleet of aircraft may require a dedicated secure, licensed band bespoke communications network. Passenger carrying AAM aircraft will be equipped with aviation band radios, and therefore fall under existing aviation communications infrastructure.

Airspace Surveillance

All aircraft operating in the NAS are subject to see and avoid regulations. For sUAS operating under Part 107, Visual Line of Sight is required between the aircraft and the Pilot (107.31) and UAS must yield right of way to all other aircraft (107.37). While the provisions of 107.31 are waiverable, the provisions of 107.37 are not, meaning that for BVLOS operations to be approved, a safety case must demonstrate to the FAA how the UAS will see and avoid all other aircraft. In lieu of having a pilot onboard, this is typically accomplished by use of an airspace surveillance sensor, such as a radar or optical sensor, that can detect aircraft that enter the UAS operational area. This information would then be used to execute an avoidance maneuver either manually or autonomously. Airspace surveillance systems may be scaled appropriately to the intended operations area. Since larger passenger carrying AAM aircraft will be operating within the current Air Traffic System, ATC radar services would be applicable where available, however there is opportunity for crossover between sUAS and larger AAM aircraft to share airspace surveillance resources. This is especially evident in the terminal environment surrounding small, uncontrolled airports where ATC radar may not be available. Larger AAM aircraft may be able to ingest this ad-hoc airspace surveillance data for situational awareness in areas where there are non-equipped aircraft or UAS operating.

2.4.3 Traffic Management

Small UAS Operations

Due to the technological and regulatory hurdles involved in BVLOS flight, current SUAs typically operate as the sole uncrewed operation in any given geographical area. As operational tempo and traffic congestion increase, the industry will begin to require UA-to-UA separation services. The FAA, NASA, and private industry, have begun to develop an Uncrewed Traffic Management (UTM) system to strategically deconflict sUAS from each other (Figure 5). In this scenario, a UAS Service Supplier (USS) would offer operators a shared, cooperative service for communicating operational intent in terms of location and time with other operators in the same geographical area to ensure deconfliction.

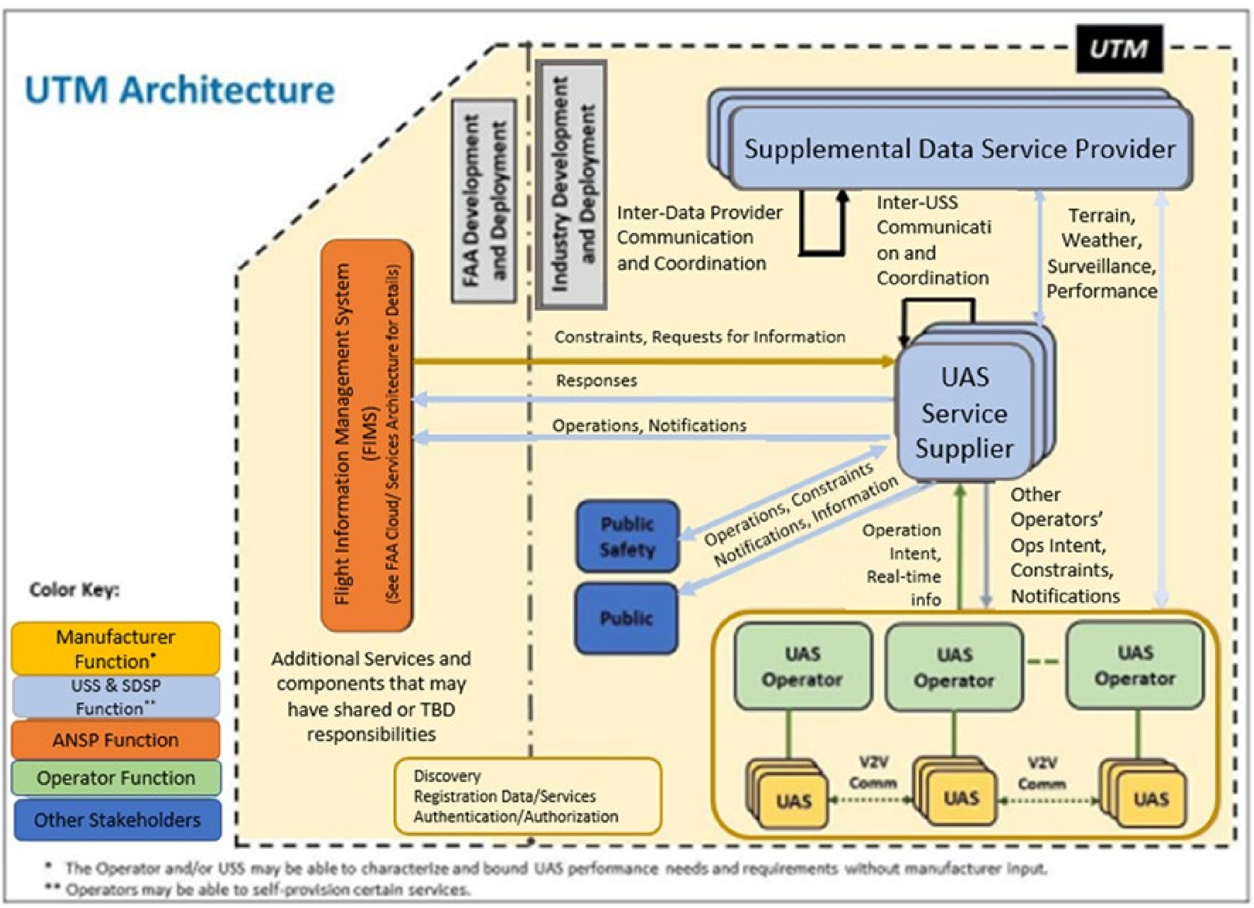


Figure 5: FAA UTM architecture. Source: FAA UTM ConOps v2.
https://www.faa.gov/researchdevelopment/trafficmanagement/utm-concept-operations-version-20-utm-conops-v20

In May of 2023, a combined team led by the Virginia Tech (VT) Mid-Atlantic Aviation Partnership (MAAP) and the Texas A&M University-Corpus Christi's Lone Star UAS Center of Excellence and Innovation (LSUASC) conducted UTM integration and test activities for the FAA under the UAS Traffic Management Field Test (UFT) program (Figure 6). The combined team, including multiple USS providers, executed a multi-day flight test campaign that demonstrated a series of UAS interactions that included strategic deconfliction, priority operations, Remote ID, and exercising FAA data services within the UTM architecture outlined in the FAA's UTM ConOps v2 and standards contained in the ASTM *Standard Specification for UAS Service Supplier (USS) Interoperability*. This test series demonstrated how 3rd-party UTM services provided by USSs and SDSPs can provide cooperative, strategic and dynamic deconfliction across public and private UAS operations below 400 AGL.

In late 2023 the FAA updated its safety risk management policy 8040.6 to include UA-to-UA collision risk as a defined hazard. This has opened the door to new FAA requirements for UAS operators to actively manage UA-to-UA collision risk via UTM strategic conflict detection (SCD) services. MAAP is currently working with a group of 7 package delivery companies to operationalize SCD as part of an FAA Keysite project in the Dallas Texas metro area.

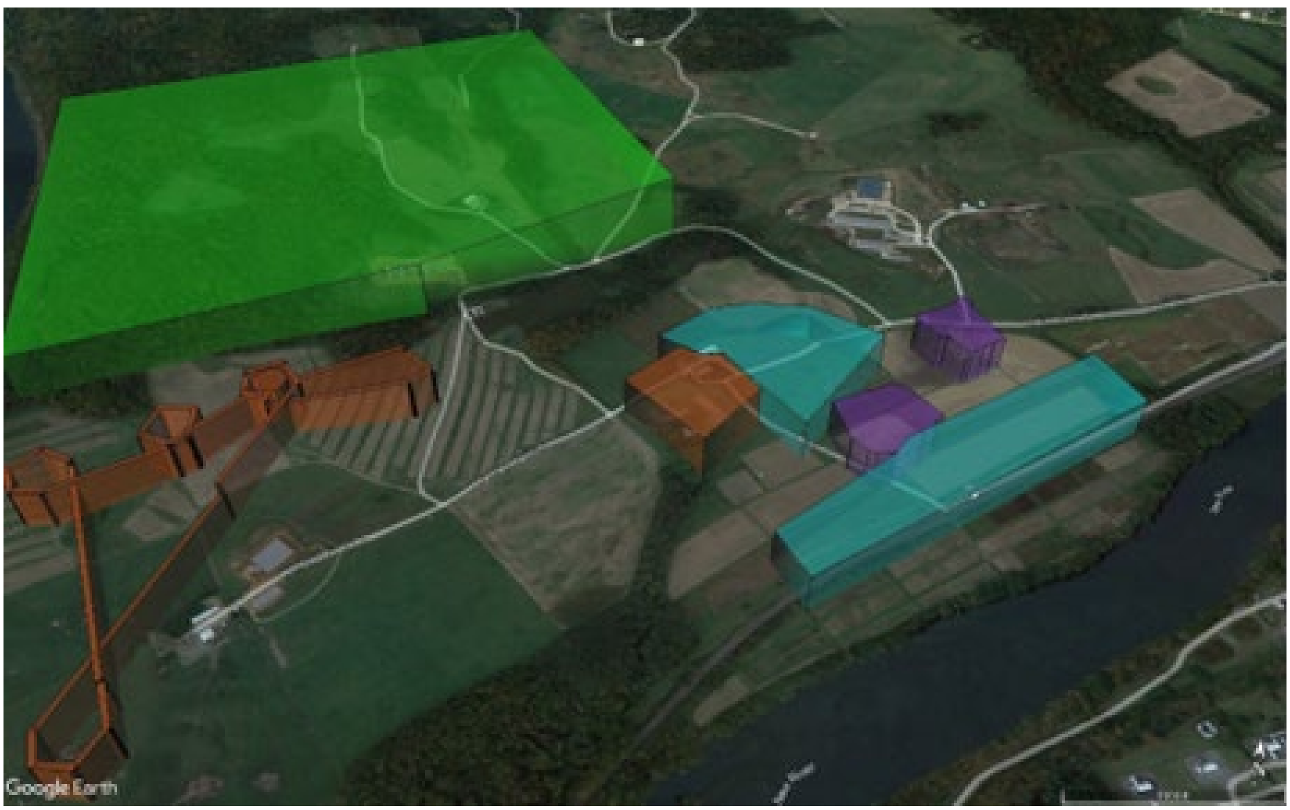


Figure 6: Example of multiple operations spatially deconflicting during testing.

Orange: ANRA, Blue: Collins, Purple: OneSky and Green: NASA.

Passenger Operations

Initially, passenger carrying AAM aircraft will be integrated with existing air traffic management systems, including established charted routes and ATC traffic separation services. As operational tempo increases plans outlined in the FAA's UAM ConOps indicate these aircraft will transition from traditional NAS integration to a more modified integration. This plan includes the creation of AAM specific corridors that aim to separate AAM aircraft from traditional air traffic and thus any associated ATC services. To accommodate this change, the FAA's UAM architecture plans call for Providers of Services for UAM (PSUs) to provide non-federated traffic management services within these corridors. This is similar to the sUAS plan utilizing the UTM architecture, however these services are meant to encompass higher altitude, passenger carrying operations.

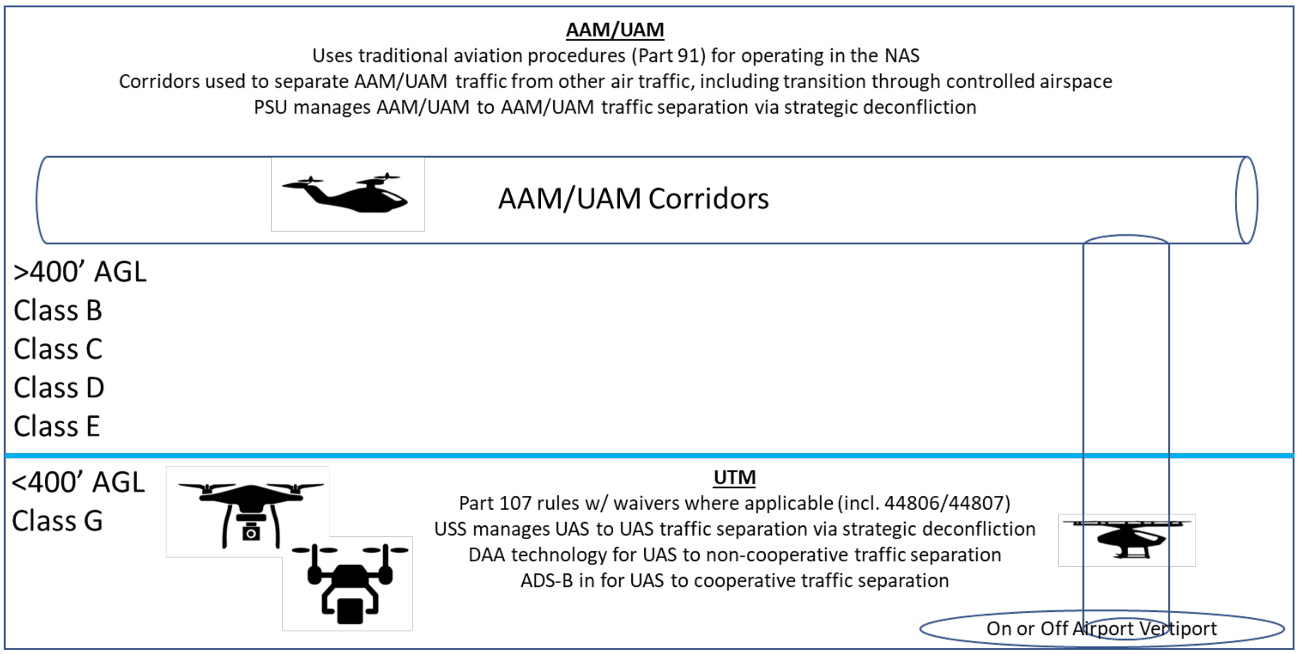


Figure 7: Example of differences between UTM and AAM airspace management

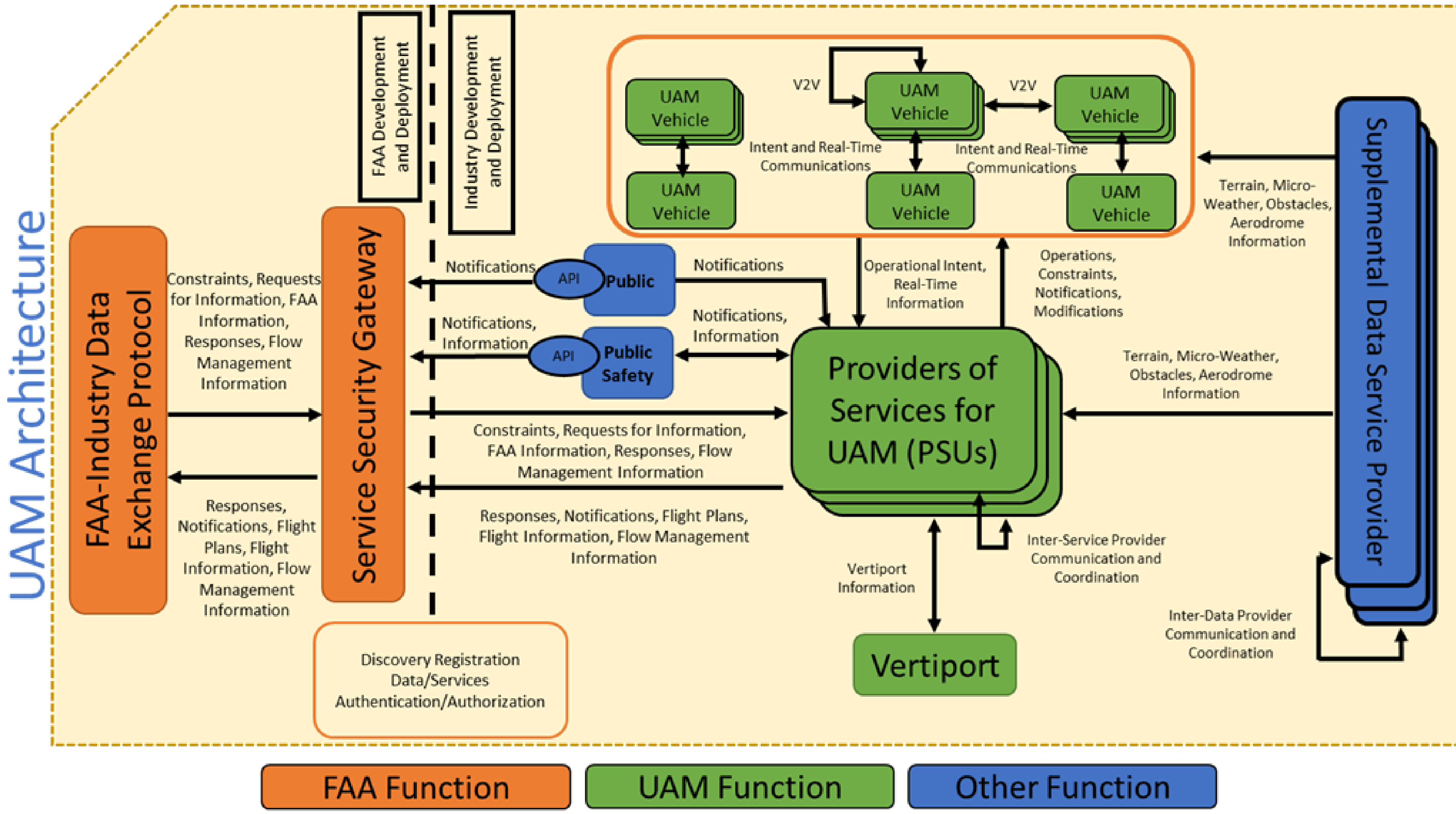


Figure 8: FAA UAM notional Architecture. Source FAA UAM ConOps 2.0.
https://www.faa.gov/sites/faa.gov/files/Urban%20Air%20Mobility%20%28UAM%29%20Concept%20of%20Operations%202.0_0.pdf

3.0 AAM Implementation Strategies

Several states have undertaken AAM infrastructure and enablement projects, ranging from R&D activities at FAA designated UAS test sites to large, full-scale implementation of assets. This section explains some of the most notable examples, including funding, infrastructure elements, and strengths and weaknesses to provide a baseline for comparison.

3.1 AAM Work in Virginia

The Virginia Advanced Air Mobility Alliance (VAAMA)

The Virginia Department of Aviation and the Virginia Innovation Partnership Corporation teamed up to form VAAMA in the summer of 2022. This collaboration brought together experts across Virginia to make recommendations around what the state might do to prepare for AAM. Recognizing a lack of clarity in timelines and the regulatory environment, the alliance decided to focus on a two-fold approach to provide near and long-term gains. With that in mind, much of the work centered around preparing for Regional and Urban Air Mobility by capitalizing on what could be done today to support smaller autonomous aircraft operations (Low Altitude Mobility). Given the similarities in challenges around certifying autonomy, mitigating air traffic risk to support BVLOS flights and delivery of goods and the importance of customer sentiment, the committee fully embraced this two-fold approach.

This study will also consider the two-fold approach as the most wholistic approach to AAM, putting forth recommendations for infrastructure that supports both near term and long-term gains.

MITRE

Non-Profit organization MITRE, who manages federally-funded research and development projects for various government agencies, recently opened a UAS test range in Orange, Va. This new facility will be dedicated to the test and evaluation of autonomous systems, drones, and counter-drone technologies to support ongoing and future work for the federal government, as well as supporting development of first responder use cases.

NASA

NASA Langley Research Center in Hampton, Va. is home to multiple UAS and AAM facilities and projects, including a UAS Flight Test Range and UAS Operations Center. These facilities support research in areas of autonomy, airspace surveillance, communications, vehicle testing, and AAM infrastructure development through projects such as the High-Density Vertiplex (HDV) Project[7]. The AAM work NASA is doing has attracted several commercial entities, including Raytheon and Longbow Group, both of whom are investing in AAM infrastructure in the Hampton area. Additionally, NASA is performing work in Virginia towards the development of Urban Air Mobility (UAM), which is a subset of AAM that focuses on passenger vehicles such as air taxi services in urban and densely populated areas. Specifically, this research[8] is exploring how

[7] https://www.nasa.gov/aeroresearch/programs/iasp/aam/hdv/description/
[8] https://ntrs.nasa.gov/api/citations/20230002647/downloads/NASA-TM-20230002647_Final.pdf

existing and supporting technologies and information exchanges may be built upon to enable future UAM operations.

Blackstone

The Allen C Parkinson Airport/ Blackstone Army Airfield is home to several UAS industry companies, including Textron Systems and UAV Pro, both of whom operate large research and operations facilities on-site. With a Tower controlled airport and access to both restricted airspace and exemptions granted to Virginia Tech's Mid-Atlantic Aviation Partnership (Figure 9), it is now routine for BKT to record more uncrewed flights per year than for traditional piloted operations. Other notable accomplishments include the development of instrument approach procedures for uncrewed aircraft systems[9] and award of a special airworthiness certificate for continued R&D efforts and training operations.

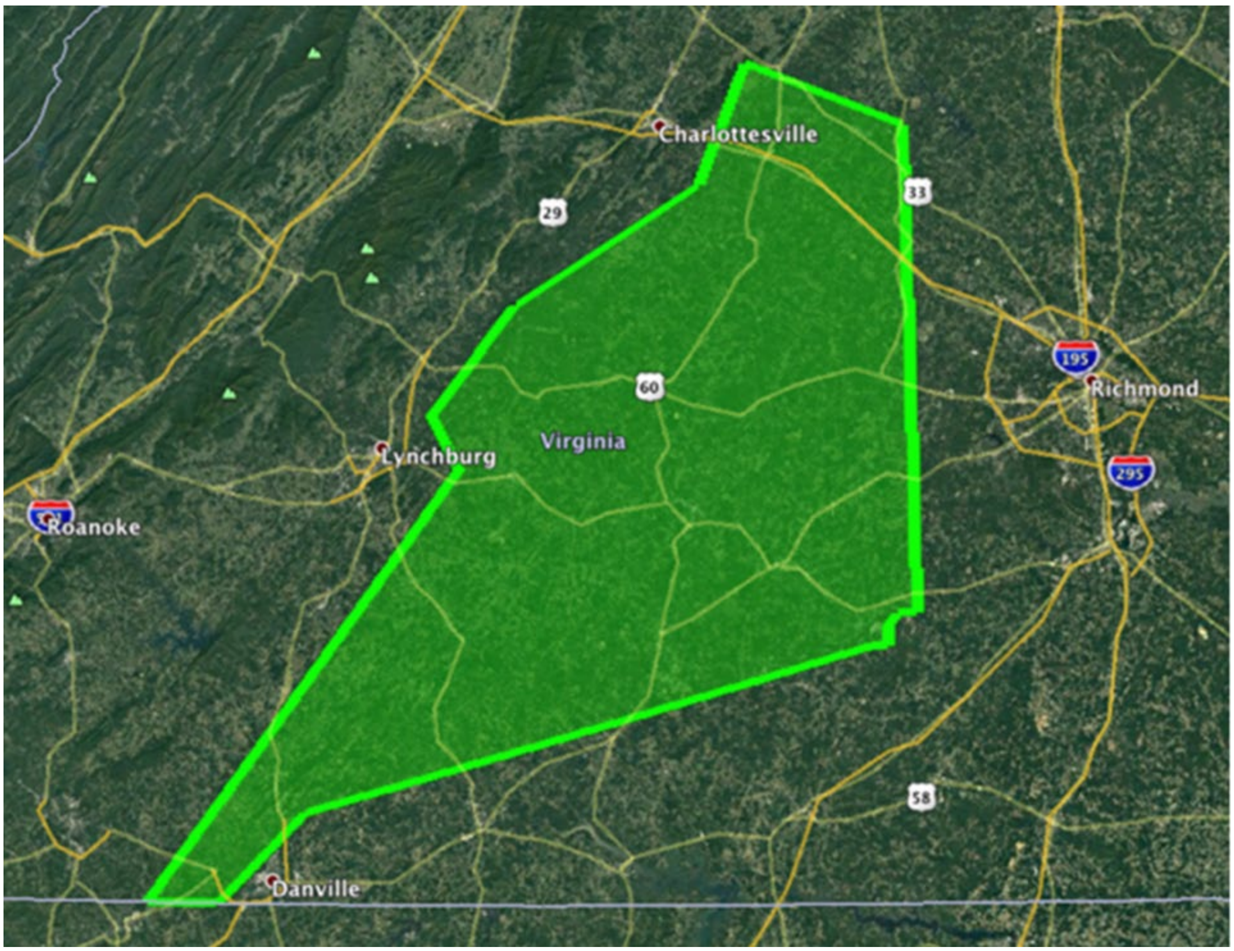


Figure 9: VT MAAP 5,000mi^2 BVLOS Test Corridor in Central Virginia

[9] https://news.vt.edu/articles/2023/02/ictas-maap-research-uas-instrument-approach.html

Mid-Atlantic Regional Spaceport (MARS)

The Virginia Spaceport Authority operates the Mid-Atlantic Regional Spaceport on Wallops Island, which includes a 3000' UAS runway, an additional landing pad for vertical takeoff and landing, and dedicated hangar space. The facility offers direct access to restricted airspace for test, evaluation, and development of UAS systems.

VT MAAP FAA-Designated UAS Test Site

MAAP leverages operational capability, aviation expertise, and robust research resources, such as the Biometrical Engineering and Mechanics (BEAM) lab for impact testing, and the Kentland Farm UAS Test Site (Figure 10), to take on the most pressing technical and operational challenges in UAS integration. MAAP leads Virginia's BEYOND team and other major federal UAS-integration efforts in areas such as research and development, test and evaluation, and safety case development. Recent work includes Unmanned Traffic Management (UTM) testing with the FAA[10], securing groundbreaking regulatory approval for commercial operations for our industry partners[11][12][13], and development of the first FAA approved Means of Compliance for UAS Operations Over People[14].

Figure 10: Virginia Tech Mid-Atlantic Aviation Partnership FAA-designated UAS Test Site in Blacksburg, Va. Testing UA for injury severity (left) and participating in an FAA research study concerning UAS traffic management (right) Source: MAAP https://maap.ictas.vt.edu/

[10] https://www.faa.gov/uas/research_development/traffic_management/field_test
[11] https://www.faa.gov/uas/advanced_operations/package_delivery_drone
[12] https://www.skydio.com/blog/dominion-skydio-drone-bvlos-waiver
[13]https://newsroom.statefarm.com/state-farm-gets-1st-national-faa-waiver/#:~:text=State%20Farm%20has%20been%20granted,catastrophic%20assessments%20through%20November%202022.
[14] https://news.vt.edu/articles/2021/12/ictas-maap-meansofcompliance.html

DOAV VA-FIX

In August of 2020, the Virginia Department of Aviation and Center for Innovate Technology created and implemented the Virginia Flight Information Exchange (VA-FIX), which allows state and local governments to share information among unmanned aerial systems (UAS) stakeholders for increased operational safety (Figure 11). This system allows Virginia state and local governments, the public, and other technology providers to interact on a platform consistent with industry standards and regulatory guidance. The Virginia Flight Information Exchange (VA-FIX) is hosted by the Virginia Department of Aviation and supports the publication of AAM advisory data by state and local public safety and government agencies to UAS Service Suppliers, Provider of Services for UAM and AAM Operators, and the public, for transparency and safety. The data is a public asset and publicly available both through a website and an Application Programming Interface providing ground rule, hazard, public safety incident, and general safety and weather advisory information. FIX supports open, authoritative public information sharing as the public Supplemental Data Service Provider (SDSP) of the Commonwealth of Virginia.

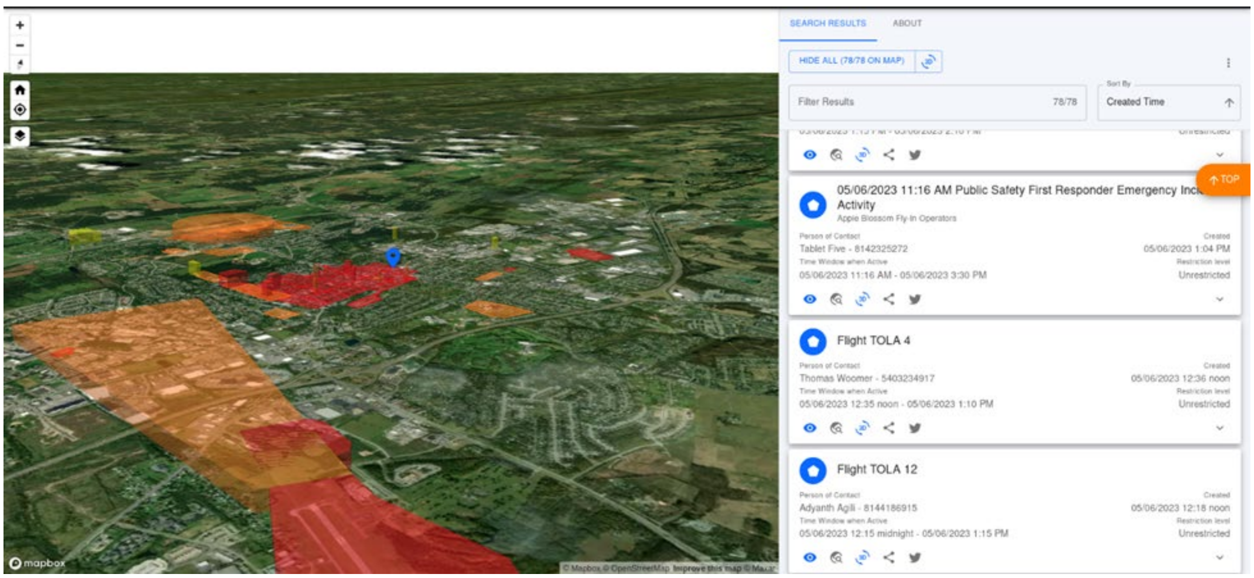


Figure 11: VA-FIX Showing Configured Advisories for the 2023 Apple Blossom Fly In, including supplemental ground rules, hazards, areas of concern, and designated ground operations areas.

Wing

Wing began work in the United States on its drone delivery program in Christiansburg, Va. as a participant in the FAA Integration Pilot Program, and its current follow-on program BEYOND, in partnership with Virginia Tech's Mid-Atlantic Aviation Partnership. Through extensive research, testing, safety case development, and community outreach and education work, Wing was able to achieve the first FAA Part 135 air carrier certificate which allows them to deliver goods for hire via aircraft (Figure 12). The Wing drone delivery service continues to be an overwhelming success in Christiansburg, with ongoing research and testing being performed to expand the capabilities and services both in Virginia and elsewhere.

Figure 12: Wing UAS commercial delivery in Christiansburg, Va. Source: Wing https://wing.com/

Drone Up

Drone Up, a Virginia based company, has been advancing UAS delivery through key partnerships with national retailer Walmart, as well as other notable companies across the country such as Quest Diagnostics and Carilion Health. In Virginia, Drone Up has partnered with Old Dominion University, Riverside Health System, and the Accomack-Northampton Planning District Commission on a USDOT grant to deliver medical supplies to the Eastern Shore and Tangier Island (Figure 13).

Figure 13: Drone Up UAS delivery services. source: DroneUp. https://www.droneup.com/

3.2 Examples of other State Funded AAM Infrastructure Efforts

Other States, including New York, North Dakota, and Ohio, have implemented AAM strategies as a means of attracting industry investment through facilitating UAS infrastructure deployment. These efforts have resulted in test ranges, or corridors, to validate technology in terms of proof of concept viability and compliance with rules and industry accepted standards. While these approaches have yielded valuable partnerships and allowed for necessary test and evaluation work to be performed, this report will highlight alternative AAM implementation strategies that may better serve the needs of the Commonwealth.

3.2.1 New York

The New York UAS Test Site[15] is one of seven FAA-Designated UAS Test Sites in the United States, and is managed by the Northeast UAS Airspace Integration Research Alliance, Inc. (NUAIR) based at the Griffiss International Airport in Rome, NY. As the major focus of the New York AAM initiatives, an initial $35 million investment was made by the state in 2016 to develop a 50-mile UAS flight corridor between Rome and Syracuse (Figure 14). In addition, a $9 million investment was made to build an indoor UAS testing facility, along with more than $25 million across five rounds of the GENIUS NY competition that offered competitors resources in exchange for winners agreeing to establish operations in the vicinity of the corridor.

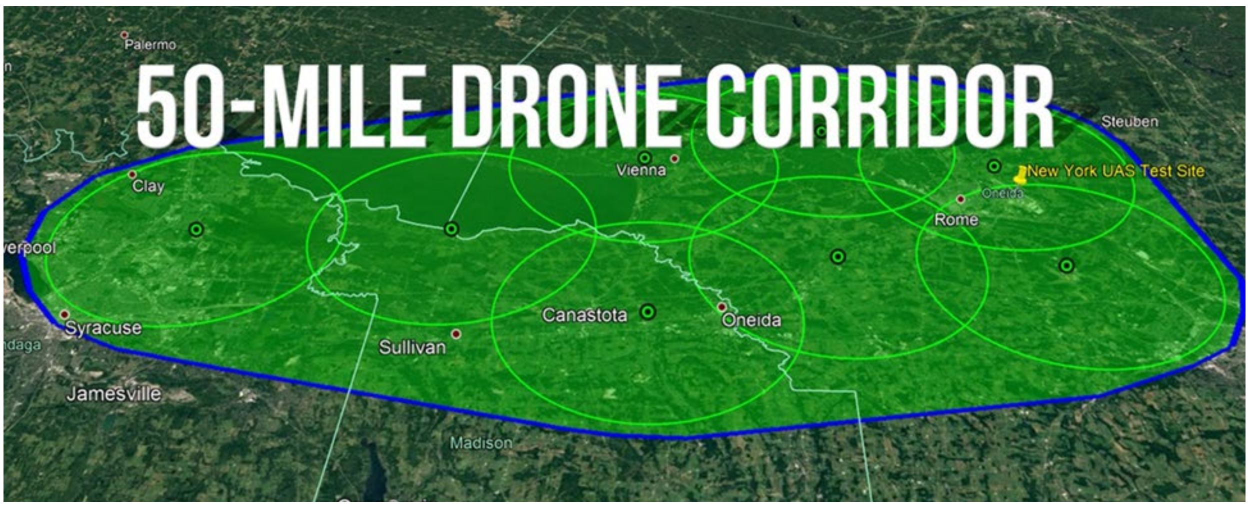


Figure 14: New York 50-mile corridor between Rome and Syracuse. Source: NUAIR https://nuair.org/2022/01/04/nuair-nyuasts-unlock-35-miles-of-bvlos-airspace/

The corridor is designed to facilitate UAS testing and evaluation efforts, and act as a magnet for industry innovators and developers. Operations within the corridor are coordinated and managed from a central operations command center located at the Griffiss International Airport (Figure 15). Technology consists of various fixed infrastructure components, including a network of nine radar sites utilizing the SRC LSTAR (V)2 and one mobile command center (Figure 16). The corridor also utilizes a robust communications network, including both licensed and unlicensed bands, and a bespoke 5G communications platform. Non-technology-based infrastructure includes use of the airport runway, a large hangar facility, and an indoor UAS test space.

[15] https://nuair.org/

Figure 15: NUAIR base operations building at the Griffiss International Airport (left), along with the operations command center work stations (right). Source: NUAIR https://nuair.org/photos/

Figure 16: Airspace surveillance infrastructure used in the New York BVLOS corridor. An SRC LSTAR (V)2 radar (left) and a mobile operations command center (right). Source: SRC https://www.srcinc.com/pdf/Radars-and-Sensors-LSTAR-V2.pdf , NUAIR https://nuair.org/photos/

Authority to operate was accomplished via a Public Certificate of Authorization (COA) issued by the FAA to conduct Public Aircraft Operations (PAO). An operator or organization with a COA may be able to fly a drone under conditions that would have otherwise been restricted even with a Part 107 drone license. For a public COA, the UAS used must be owned or leased as public assets. In April of this year, the FAA granted a new civil authority to the NY UAS Test site allowing them to operate non-public owned or leased UAS under 300 lbs. throughout the corridor, and be compensated for operations. The new authorization allows for:

> *"research, development, testing, evaluation, operational suitability demonstrations, familiarization, crew training flights, likely failure and specific demonstration testing, noise testing, flights to substantiate major design changes, flights to show compliance with the function and reliability requirements of the regulations, market survey, and flights that are part of the durability and reliability-based means of compliance type certificate (TC) process, with uncertified UAS."*

To date, the corridor has hosted over 5,000 flights consisting of test and evaluation of various platforms, use cases, and associated elements. To date, no waivers for commercial operations have been granted utilizing the corridor.

One of the major strengths of the New York BVLOS corridor is the robustness of the infrastructure that has been deployed. This is credited in large part to the partnerships that have been formed with major industry companies, including SRC, SAAB Sensis Corp., Lockheed Martin, AURA, and Thales, and others to create airspace surveillance, communications, and data management solutions. One of the major contrasting points of the NY approach to AAM infrastructure vs. the MVI concept proposed in this report is its one size fits all, "If you build it they will come" model. The corridor is limited to a specific geographic location, funneling all resources to a specific region of the state. While access to the infrastructure and authorizations required to conduct meaningful research is a valuable industry resource, it only encompasses a small portion of the AAM ecosystem. Commercial users looking to stand up financially viable AAM business models using this infrastructure are limited to a specific geographic area that coincides with the BVLOS corridor, which may not align with their target market or customer base. Further, it is not clear that there is a revenue neutral funding model for the operations and maintenance of this corridor.

3.2.2 North Dakota

The North Dakota Northern Plains UAS Test Site (NPUASTS)[16] is based in Grand Forks, ND and is also one of the seven FAA designated UAS Test Sites. The NPUASTS administers the state's AAM efforts through the Vantis network, a $48 million project to create a network of AAM infrastructure across ND, with another $30 million slated in the 2023-2025 budget for continued expansion. Vantis was developed with the goal of enabling UAS flight across the state via widespread infrastructure deployment in a phased approach, starting in the northwest and expanding eastward (Figure 17).

[16] https://www.vantisuas.com/

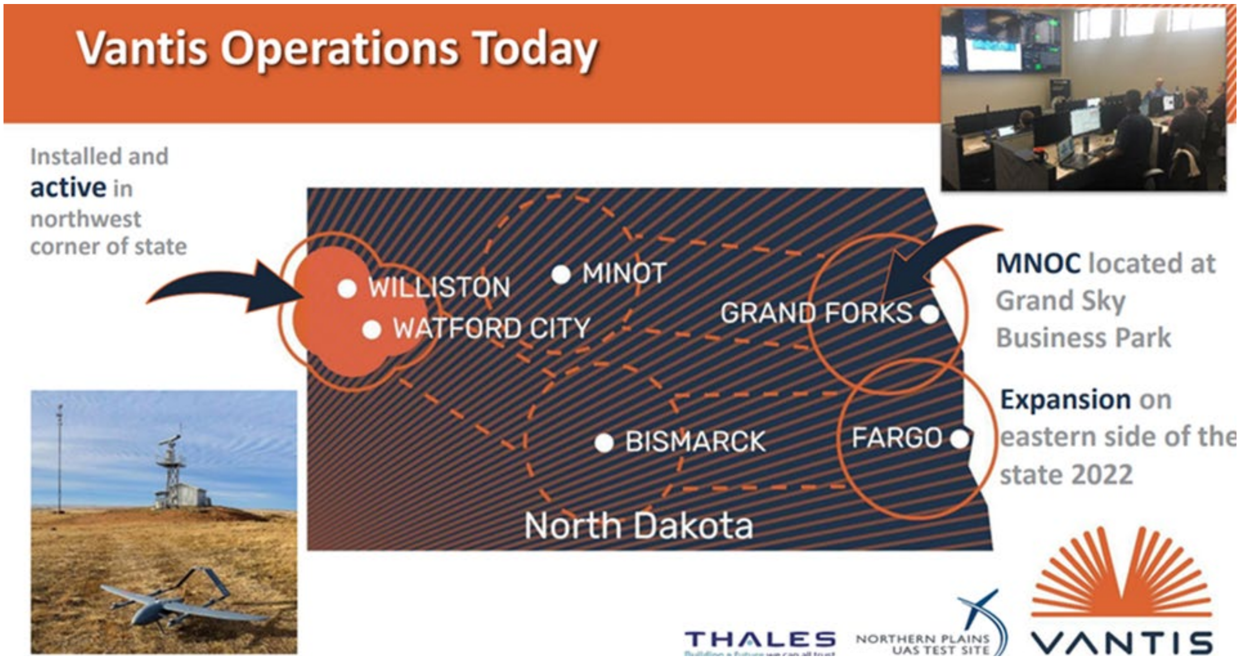


Figure 17: North Dakota Vantis network map of current and future coverage areas. Source: Vantis https://cdn.ymaws.com/nasao.org/resource/resmgr/convention/2022_convention/02-a_future_in_aviation-nd.pdf

Similar to the NY model, the Vantis infrastructure is designed to facilitate UAS testing and evaluation efforts in conjunction with UAS Test Site efforts, with the additional goal of duplicating the infrastructure model in other areas and expanding to enable commercial operations to utilize the service. Initial deployment around the Williston and Waterford City areas consist of a network of Terma SCANTER 5202 radars for airspace surveillance (Figure 18). A secure communications network consisting of both licensed and unlicensed band command and control radios is also utilized. Data is sent and received via the statewide STAGEnet fiber network, where flights are monitored and controlled from the Vantis Mission & Network Operations Center at the Grand Sky Business park in Grand Forks (Figure 19).

Figure 18: Airspace surveillance infrastructure used as part of the North Dakota Vantis network. Source: Terma. https://www.terma.com/news-events/news/news-archive/protecting-north-dakota-skies-for-safe-unmanned-aircraft-system-operations/

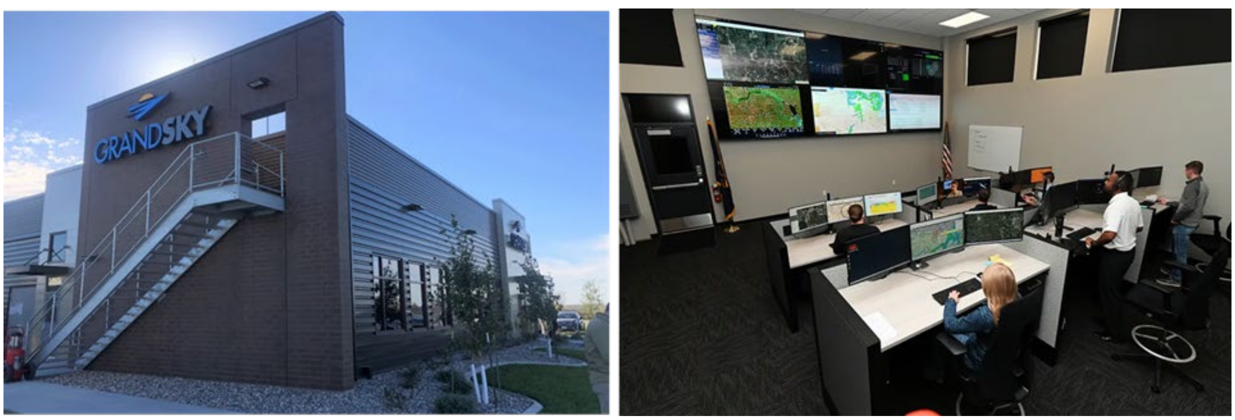


Figure 19: The Vantis Mission and Network Operations Center at the Grand Sky business park in Grand Forks, ND. Source: Thales. https://onboard.thalesgroup.com/faa-grants-initial-approval-allowing-bvlos-drone-flights-on-vantis-north-dakotas-drone-system/

For specific Test Site activities, including civil operations, the FAA has issued a civil COA similar to the one issued to the New York (and Virginia) UAS Test Sites, which is the waiver issued under authority of 49 U.S.C. 44803(c). This waiver allows the Test Site and qualifying customers to conduct operations for UAS weighing under 300lbs. in furtherance of testing, research, and development.

Outside of Test Site activities authorized under 44803(c), non-Test Site users may gain access to the Vantis infrastructure via a third-party, FAA authorized UAS Service Supplier (USS). This service allows for registered users to access localized surveillance data from the network to display surveillance tracks of crewed aircraft while operating within the Vantis service volume. Recently. The FAA granted uAvionix, a private UAS technology company, approval[17] to use the Vantis

[17] https://www.faa.gov/media/70426

network for Beyond Visual Line of Sight research and evaluation testing outside of the requirements listed in a 44803(c) COA.

One of the major strengths of the Vantis approach to AAM infrastructure is how it is configured to enable both expansion and commercialized use. Again, similar to the New York approach, the infrastructure components are the result of numerous public/private partnerships with technology providers such as Collins Aerospace, L3Harris, Thales, Airspace Link, and others. By using the infrastructure as a service for users to base their safety case upon, it opens up commercialization of the network by eliminating the need for individual operators to stand up their own airspace monitoring solution, which may be a major roadblock for many due to the costs and complexity involved. One of the major contrasting points between the North Dakota approach and the proposed MVI approach is its implementation model, which takes the largest, most robust solution and replicates it across as much of the state. This model may not be the most cost- effective method of addressing needs, and may require long term subsidies for commercial viability.

3.2.3 Ohio

The Ohio Department of Transportation formed the Ohio Uncrewed Aircraft Systems Center[18] in 2013 as part of the DriveOhio smart mobility initiative. The Ohio UAS Center manages and performs UAS operations on behalf of the Ohio DoT is a shared resource for other state and local UAS programs. In 2019, the Ohio UAS Center partnered with the Air Force Research Laboratory (AFRL) to facilitate UAS system testing, certification, and commercialization efforts in the state. The cost of the program was equally shared between ODOT and AFRL with each contributing $5 million towards development. The result is a 200 square mile test range in the vicinity of the Springfield-Beckley Municipal Airport in Southwestern Ohio (Figure 20).

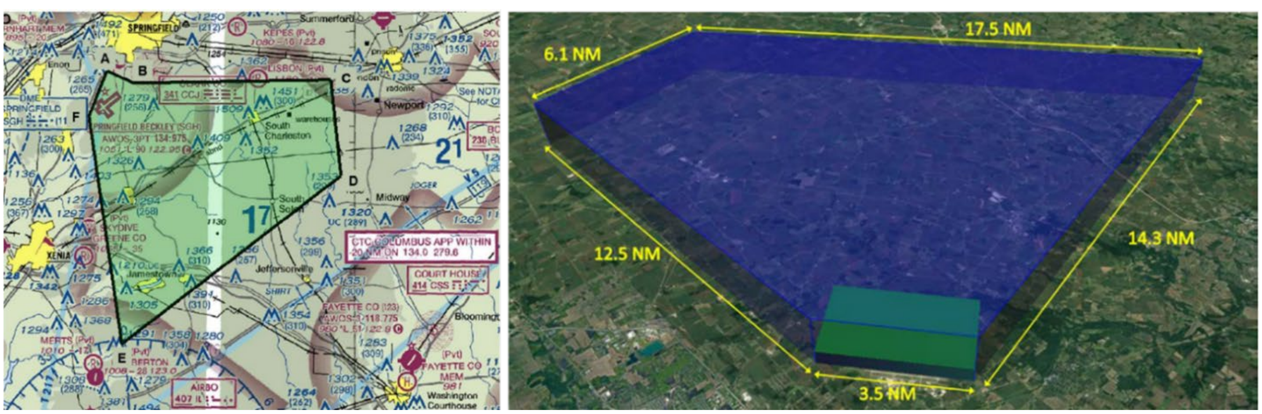


Figure 20: Ohio Skyvision coverage area in southwestern Ohio. Source: Ohio Unmanned Aviation Systems Center https://uas.ohio.gov/skyvision/airspace/airspace

In contrast to the New York and North Dakota infrastructure, the SkyVision system utilizes data feeds from three FAA radar sites, including the ASR-9 at Dayton International Airport, the ASR-9 at Columbus International Airport, and the CARSAR long range radar at London. Data from these three overlapping radar sites provides airspace surveillance to allow UAS flight operations to safely integrate with traditional air traffic. Access to the FAA radar data was accomplished via

[18] https://uas.ohio.gov/skyvision

a Department of Defense sponsorship from the AFRL. Instead of utilizing a fixed site command center like the NY and ND sites, the Ohio radar data is fed into a mobile operations command center, where it is combined with UAS telemetry data and used by SkyVision staff to ensure separation (Figure 21 and Figure 22). Additional infrastructure and backhaul networking is accomplished with Ground Control Station (GCS) translators, system health monitoring, micro-weather services, system integration hardware and software.

Figure 21: Ohio SkyVision Mobile Operations Command Center. Source: AFRL. https://www.afrl.af.mil/Portals/90/Documents/HQ/SkyVision_Factsheet_0419.pdf?ver=XL3TjD95sxs9hhXMQ8Hn7A%3D%3D

Figure 22:Ohio SkyVision Mobile Operations Command Center radar display and work station. Source: Ohio UAS Center. https://uas.ohio.gov/skyvision/How+to+Access

Authority to operate was accomplished via Certificate of Waiver or Authorization (COA) that allows AFRL to launch and recover flights from the Springfield-Beckley Airport and operate within the test range from 1000' above ground level up to 10,000 Mean Sea Level, while providing their own review and safety approval processes. In addition, civilian entities wishing to utilize the test range may apply for use on a case-by-case basis.

While the Air Force Research Laboratory is the primary user of the SkyVision system, non-DoD entities may be eligible to use the airspace. Based on the flowchart in Figure 23, if an operator has a DoD sponsor, the AFRL will manage their use of the airspace. If there is not a DoD sponsor, the

AFRL will evaluate the system and decide if it wants to sponsor the flights through a cooperative agreement. Other, non-DoD related operations would coordinate through the Ohio UAS Center for access.

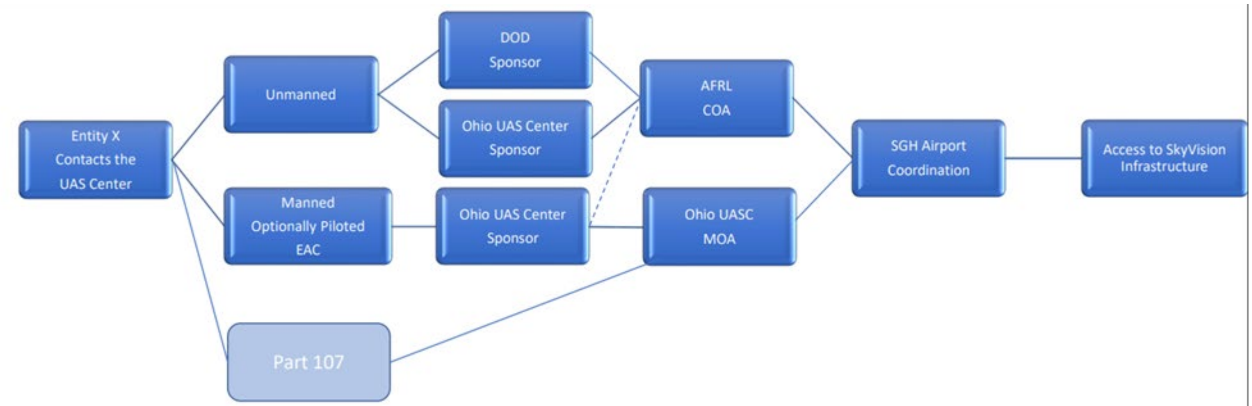


Figure 23: Flowchart depicting means of access for the SkyVision system. Source: Ohio UAS Center. https://uas.ohio.gov/wps/wcm/connect/gov/62704c3a-7b79-4e95-8f2b-86b65cf2c191/SkyVision+Access+Information.pdf?MOD=AJPERES&CONVERT_TO=url&CACHEID=ROOTWORKSPACE.Z18_M1HGGIK0N0JO00QO9DDDDM3000-62704c3a-7b79-4e95-8f2b-86b65cf2c191-nUR9KOh

One of the major strengths of this infrastructure model is the use of existing airspace surveillance resources. The FAA air traffic control system has already provided the necessary airspace surveillance infrastructure in the area, and tapping into this resource has resulted in a major cost savings, as reflected in the difference between the SkyVision costs and the NY BVLOS corridor or the ND Vantis network. This approach may be an excellent model for implementing a small part of an overall AAM strategy by utilizing existing resources where appropriate.

As with the New York test range and corridor, one of the major differences between the Ohio AAM infrastructure and the MVI concept is its geographical constraints. This test range was purpose built for the specific use case of R&D testing, and only represents a small fraction of the AAM ecosystem. While this solution worked well for this particular area and use case, it may be limited in commercial application due to the sensitive nature of the FAA radar data utilized.

3.2.4 Various Other State Initiatives

Texas

In 2021, the Texas Legislature passed Senate Bill 763 in the 87th Regular Session requiring the Texas Transportation Commission to establish the Urban Air Mobility Advisory Committee "to assess current state law and any potential changes to state law that are needed to facilitate the development of urban air mobility operations and infrastructure in this state." The Committee has made recommendation across AAM focus areas of Airspace, Infrastructure, and Technology, including:

- Development of a state funded AAM/UAM research facility
- Integration of AAM/UAM operations within the Texas Airport System Plan
- Direct the State to work with municipalities to integrate AAM into their communities

In addition, the Committee has established several working groups to address the various aspects of AAM in terms of Airspace and Infrastructure, Technology, Safety and Security, and Commerce and Community Integration.

Michigan

The Michigan Mobility Funding Platform (MMFP) is a grant program managed by the Michigan Office of Future Mobility and Electrification (OFME), which was created by the Michigan Economic Development Corp. and the Michigan DoT to develop new mobility solutions across the state. This program provides grants to mobility and electrification companies that wish to deploy their technology solutions in Michigan. The OFME facilitates work towards exploring and implementing transformative mobility solutions by bridging the gap between state government, regulators, academia, and private industry. As part of this effort, the OFME routinely partners with the Michigan Unmanned Aerial Systems Consortium to facilitate test and evaluation of autonomous aircraft that may contribute to Michigan's future mobility goals of building a stronger economy through more equitable and environmentally conscious transportation solutions.

Michigan House Bill 5349 – States that is a political subdivision enacts a zoning ordinance relating to AAM it must not grant an exclusive right to an operator to a vertiport and must promote a nonexclusive right and reasonable access to AAM operators to the vertiport. Provides state preemption of AAM, AAM aircraft, and AAM aerial operation.

Florida

Florida House Bill 1275/Senate Bill 1506 – Requires the Development of a strategic infrastructure investment plan to address mobility infrastructure and secure the state economic driver, with a focus on AAM implementation.

Florida House Bill 1301 – Creates a grant program for funding to develop and establish vertiports in the State.

Florida Senate Bill 1032 – Reorganizes the makeup of the transportation planning commission and MCOs. Requires the long-range 20-year transportation plan to include AAM and autonomous/electric vehicles.

Florida Senate Bill 1362 – Requires the DOT to address the need for vertiports and other advanced aviation infrastructure in the statewide aviation plan, designate an AAM SME, lead a statewide educational campaign, provide local jurisdictions with a guidebook and technical resources to support planning, and to conduct a review if airport hazard zone regulations. Defines Terms.

4.0 Minimum Viable Infrastructure

In the context of this report, Minimum Viable Infrastructure refers to the concept of developing risk mitigation strategies that enable AAM use cases by deploying technology in a manner that is specific, effective, and economically viable. This strategy examines each individual use case, along with contributing factors such as geography, environment, and end user goals, and tailors the enabling infrastructure to solve these challenges on a case by case basis. The MVI strategy takes a holistic approach to AAM by acknowledging that the unique problem sets presented for individual use cases require scaled solutions, therefore a "one size fits all" approach to AAM infrastructure deployment may be limiting.

4.1 Minimum Viable Infrastructure Concept

Just-in-Time and Lean manufacturing are concepts that many companies have implemented to help control risk, eliminate wasteful practices, and focus on adding value to their customers. This is accomplished by producing high quality products that meet demand, vs. in surplus or in anticipation of potential needs. The Minimum Viable Infrastructure concept follows these time-proven models of success by matching scaled solutions with identified needs. Instead of pushing expensive, resource consuming, and intricate infrastructure models out that may be in excess and/or in anticipation of needs, the MVI concept pulls customer needs to create a value stream that is optimized, efficient, and sustainable. This concept seeks to maximize the effectiveness of Commonwealth resources by investing in strategies that enable AAM use cases in a well thought out and fiscally responsible manner. While additional MVI models may be added, the following section provides examples of different strategies that highlight how AAM infrastructure may be implemented based on identified needs.

4.2 MVI Strategies

The MVI strategies discussed here represent examples of how infrastructure assets may be scaled in direct response to safety mitigation strategies on a case by case basis. This approach takes-into-account location specific challenges and opportunities, the complexities of individual and unique problem-sets, and the various requirements for gaining regulatory approval. By providing a "toolkit" of solutions, this strategy allows for various AAM infrastructure to be deployed independently of other AAM infrastructure efforts throughout the Commonwealth, while still being connected through a common data network. Scaled responses to direct AAM infrastructure needs ensures the system is agile enough to adapt to requirements while eliminating risk surrounding overbuilding and overspending. The following sections introduce several distinct MVI strategies.

4.2.1 Wide-Area Low-Cost MVI

The most basic MVI strategy involves wide-area deployment of low-cost assets that may form the groundwork for an overall AAM strategy. These low-cost assets would be deployed at select locations and serve as data inputs to the Commonwealth AAM network. The phrase "wide area, low-cost" is meant to represent the idea that numerous units may be deployed across a larger geographical area for similar cost as a single, large, higher cost, fixed infrastructure element. While these wide-area low-cost assets may not directly enable a wide range of AAM use cases, their value to the overall AAM infrastructure network grows exponentially as more assets are deployed.

These type assets are meant to be gap fillers in essential background data such as weather, cooperative air traffic monitoring, communications and data relays, and other inputs that aid in the decision making and overall situational awareness for the Commonwealth AAM network as a whole, including enhancing safety and situational awareness for traditional aviation. Placement of these type infrastructure assets may be seen as nodes in the overall network that are placed in areas where gaps in situational awareness data exist, such as underutilized general aviation airports, locations across the Commonwealth that lack aviation weather reporting capabilities, and mountainous areas where communications challenges may exist. Creating these "nodes" sets the groundwork for future expansion by providing numerous access points to the AAM network that needs-based expansion efforts can more easily plug into.

4.2.2 Short-Range Fixed-Site MVI

The Short-Range Fixed-Site MVI strategy refers to deploying AAM infrastructure assets that are meant to support ongoing localized, small scale use cases. These infrastructure elements would directly address individual area and use case needs by focusing on development of risk mitigation strategies that satisfy applicable rules, regulations, and standards to enable localized operations. This concept builds upon the wide-area low-cost strategy by adding additional data inputs to the network in response to a direct need, such as airspace surveillance capabilities in a defined radius of a specific geographical area. Based on current industry capabilities, short-range may be referred to as coverage extending less than 3 miles from an infrastructure emplacement, and typically applies to airspace surveillance technologies in particular. These assets are also referred to as fixed-site since they are meant to enable ongoing operations in a specific location. The smaller Size, Weight, Power requirements, and Cost (SWaP-C) of these infrastructure assets lend themselves to greater flexibility in emplacement options, such as mounting to existing infrastructure like water towers, buildings, and communications towers. As with most other AAM infrastructure assets, these may be networked together to form a larger coverage area for a more customized scaling of deployment and emplacement per use case needs. The lower cost point of short-range sensors also creates greater opportunities for entry into the AAM ecosystem where financial barriers may have previously existed.

4.2.3 Medium-Range Fixed-Site MVI

The Medium-Range Fixed-Site MVI strategy refers to deploying AAM infrastructure assets that are meant to support localized routine operations pertaining to a specific use case. As with the Short-Range Fixed-Site strategy, these infrastructure elements would directly address individual area and use case needs by focusing on development of risk mitigation strategies that satisfy applicable rules, regulations, and standards to enable the intended operations. Again, this concept builds upon the wide-area low-cost strategy by adding additional data inputs to the network in response to a direct need in a defined radius of a specific geographical area. Based on current industry capabilities, medium-range may be referred to as coverage extending between 3 and 10 miles from an infrastructure emplacement, and typically applies to the detection range of airspace surveillance technologies in particular. These assets are also meant to be fixed-site since they are emplaced to enable ongoing operations in a specific location. This class of infrastructure asset will have a higher SWaP-C than short-range due to the increased capabilities, but may still lend themselves to flexible emplacement options by mounting to existing structures or dedicated options. As with most other AAM infrastructure assets, these may be networked together to form a larger coverage area for a more customized scaling of deployment and emplacement per use case needs, including the formation of an airspace surveillance corridor that expands capabilities to include additional use cases. The lower cost point of medium-range vs. long-range sensors also creates greater opportunities for entry into the AAM ecosystem where use cases require solutions that are more robust than short-range, but do not justify long-range capabilities or expenditure. This is a prime example of the MVI scaled response strategy of providing a customized solution set to a specific need.

4.2.4 Mobile MVI

The Mobile MVI strategy refers to emplacing medium-range airspace surveillance technology on a mobile platform such as a trailer or a dedicated vehicle that acts as a Mobile Operations Command Center (MOCC). While fixed-site medium-range infrastructure supports routine ongoing operations, these mobile assets are meant to support localized non-routine operations pertaining to incident response where required supporting infrastructure is either not present or is cost prohibitive. By offering a mobile on-demand solution to AAM infrastructure, gaps in service may be filled on an as-needed basis versus permanently emplacing assets where they may be underutilized. The mobile MVI may also include air assets such as UAS with a modular payload capacity for responding to a variety of situations and use case needs, including highway incidents, weather events, and dynamic emergency incidents.

4.2.5 Long-Range Fixed Site MVI

The Long-Range Fixed-Site MVI strategy refers to deploying AAM infrastructure assets that are meant to support multiple use cases across a wider geographical area. Based on current industry capabilities, long-range may be referred to as coverage extending beyond 10 miles from an infrastructure emplacement, and typically applies to the detection range of airspace surveillance technologies in particular. These infrastructure elements would address more broad use case needs in contrast to the specific needs addressed by the short and medium range options. The long-range fixed-site approach is similar to the strategy described in North Dakota, with the exception being this is only one of several available options for AAM infrastructure deployment. This strategy may be used where a demand exists for larger scale operations footprints and tempos from one or more entities wishing to participate in AAM activities in a particular area of the Commonwealth, most notably commercial operations. This MVI strategy may be best suited to enabling demand for commercial AAM services to be met, and act as a magnet for multiple commercial users and industry as a whole. Instead of focusing on meeting the needs of one specific use case, an overall implementation schema may be developed for this strategy that helps facilitate entry for a broader range of end users.

4.3 Standardization of Data Availability

The entirety of the AAM infrastructure, regardless of specific strategy, may be connected via a backhaul data network that allows for seamless ingestion and dissemination of information on a standardized platform. The MVI concept would allow for data inputs from any node connected to the system to be shared with any other authorized user, regardless of location (Figure 24). This method would allow for users to access the data required to support their operations without the need for it to first be relayed by a centralized command center, enabling independent, self-supporting AAM operations across the network.

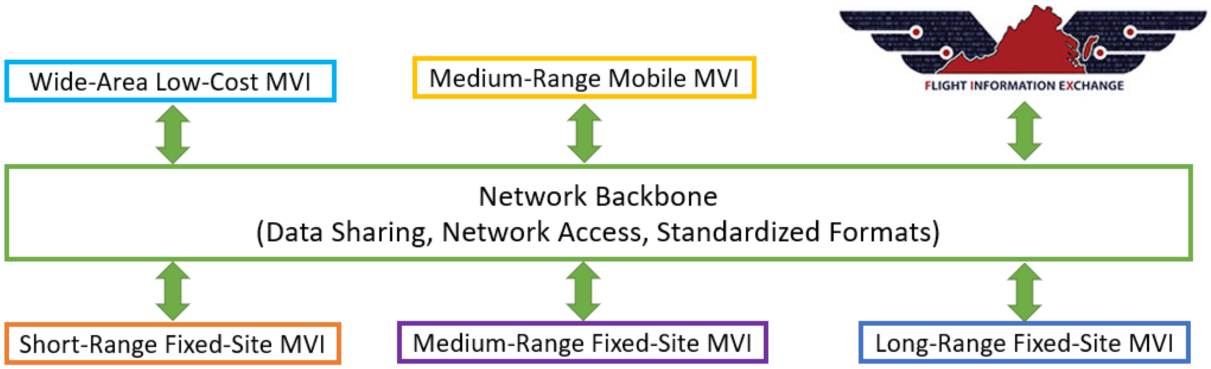


Figure 24: A backhaul network would serve as the central access point for all data across the AAM ecosystem, facilitating data sharing, oversite and control, and standardization of data formats.

Figure 25 illustrates the concept of a mobile unit utilizing surrounding communications and data inputs on the AAM network in addition to its onboard airspace monitoring capabilities to support operations. Additionally, other stakeholders including State and Local agencies may gain access to the mobile unit's data feeds for situational awareness and coordination.

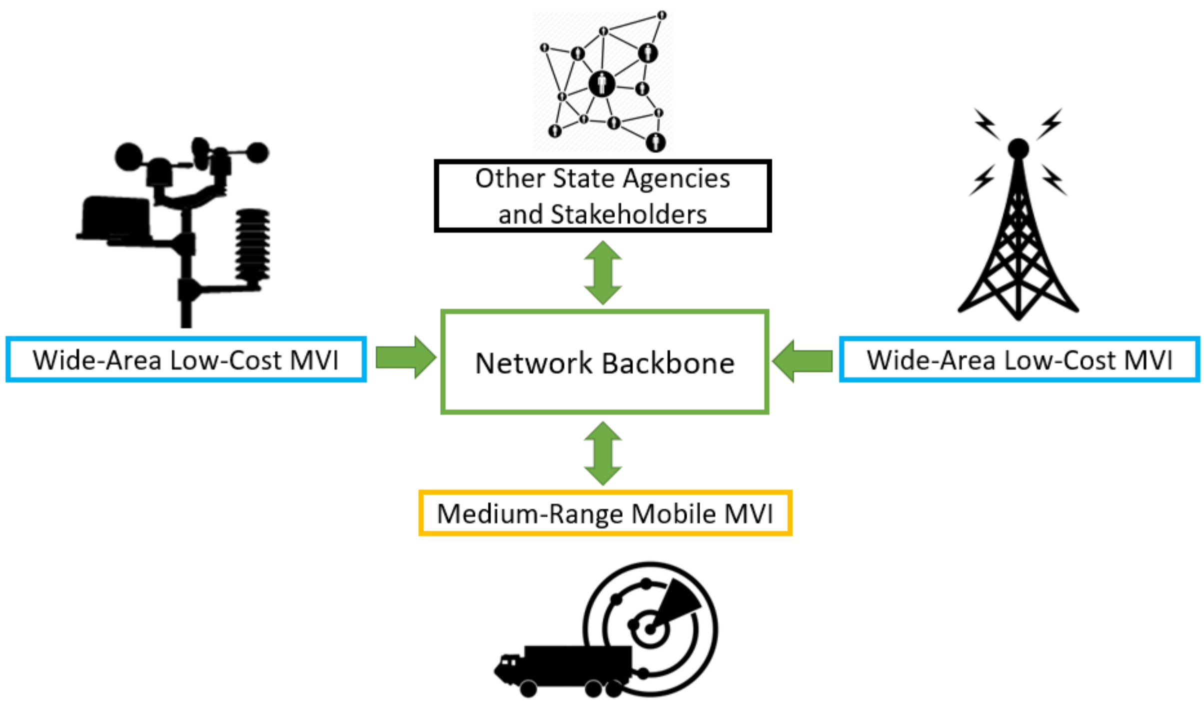


Figure 25: Example of a mobile unit accessing data from other nodes in the system to support its operations, such as weather information and communications relays, while other stakeholders access the mobile unit's data feeds for situational awareness.

4.3.1 Considerations for General Aviation

An additional benefit of AAM infrastructure connected through a shared network is the ability to provide specific levels of access to sensor feeds that are relevant to each user's operations. In the case of General Aviation, enhanced situational awareness and safety may be achieved through access to sensor data, particularly that provided by the Wide-Area Low-Cost sensors such as Remote ID readers, weather information, and real-time information from services like VA-FIX. This may be accomplished through a data access portal that displays information from MVI assets that may not otherwise be available to general aviation pilots, such as output from non-cooperative aircraft sensors and Remote ID readers that can reduce the likelihood of collision with drones or other aircraft. MVI weather may allow for low-altitude weather information to be gathered and displayed at airstrips that previously did not have access to this infrastructure, increasing pilot situational awareness during critical approach portions of flight. Ideal output integration would appear as another layer inside Electronic Flight Bags, such as Foreflight and Garmin Pilot.

Additional considerations for General Aviation include the ability for GA airports to host MVI components, including airspace surveillance sensors, weather sensors, communications towers, and vertiports. This may be a particularly attractive concept for underutilized airports across the Commonwealth to increase revenue and attract additional users, as well as contribute to the overall safety of the terminal environment.

4.3.2 Standardized Outputs

Data outputs across the AAM infrastructure network may be standardized so that regardless of location, operation, or end user, all outputs are provided in the same data format and on the same user interface. Among the many benefits of standardization are assurance of continuity throughout the network, centralized training and compliance administration, and the ability to seamlessly add additional services without redesigning user interfaces. One method of ensuring standardization of data is by implementing the UAS Traffic Management (UTM)[19] model proposed by the FAA as shown in both Figure 5 and below in Figure 26. Within the UTM architecture, the Supplemental Data Service Providers (SDSPs) would be the AAM infrastructure that provides all the data points into the system such as weather and airspace surveillance. A UAS Service Supplier (USS) would take all the data points from the SDSPs and provide it to the end users in a standardized format. The USS would act as the gateway to AAM infrastructure access, and provide each individual user the specific data from the AAM network they needed to enable their intended operation. Figure 27 shows examples of USS displays that provide end users with data ranging from own ship UAS telemetry feeds to SDSP information such as weather and airspace surveillance, to notifications from Federal, State, and Local authorities. By utilizing a USS as the gateway for initial AAM infrastructure access, particularly for sUAS operations, it ensures user compliance with rules and requirements, grants access to the specific data the end users are authorized to receive, and provides accountability and assurances for the accuracy and timeliness of the data.

[19] https://www.faa.gov/sites/faa.gov/files/PL_115-254_Sec376_UAS_Traffic_Management.pdf

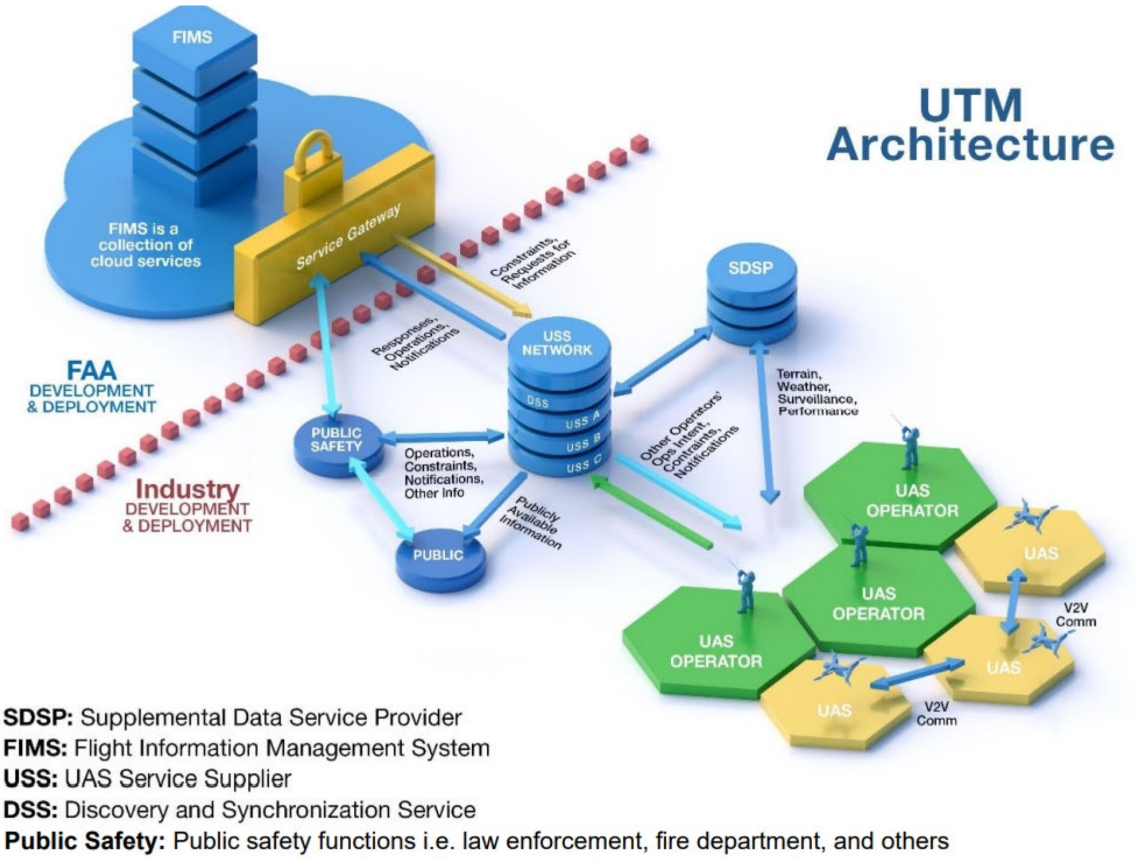


Figure 26: FAA UTM architecture diagram.

Figure 27: Examples of USS user interfaces. Source: Skygrid (left), Airspacelink (center), ANRA (right).

As larger AAM use cases are implemented and continue to grow in frequency and density of operations, the UAM architecture (Figure 5) would be implemented. In this scenario, PSUs would coordinate separation of AAM/UAM aircraft from each other and corridors would be created to segregate operations from traditional aircraft.

4.3.3 Central Administration

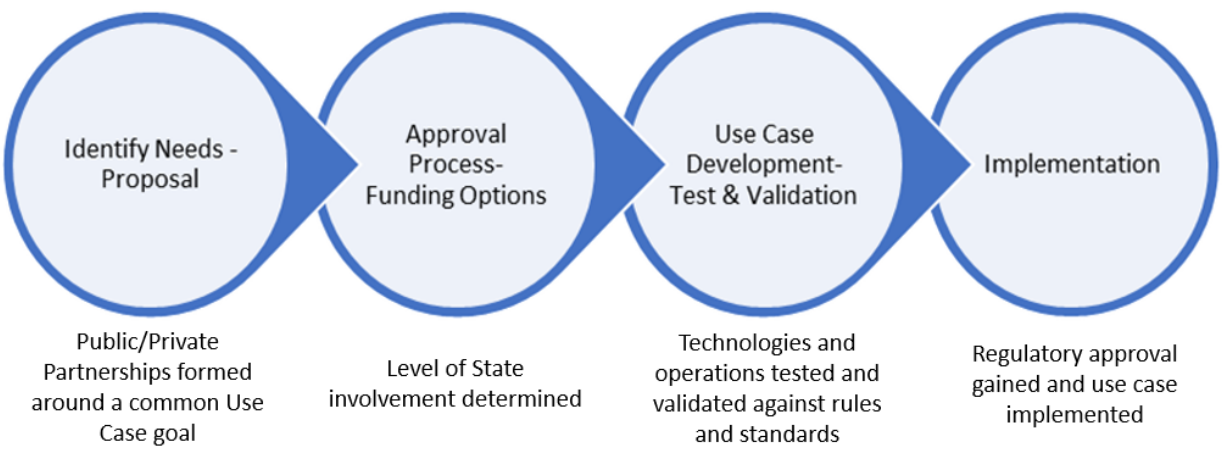
In addition to providing a common connection point between AAM infrastructure data, a backhaul data network would allow for the central administration and oversite of the entire network from any authorized access point. This access would facilitate essential administrator functions such as system health monitoring, maintenance and access control, as well as overall situational awareness across the entire AAM network for coordination between Virginia State agencies at both the state and local level. Instead of coordinating all operations through a central command center, each user's login would grant them access to the data required to support their operations independently, i.e. a secure virtual network. In this configuration, DoAV may administer and monitor Service Level Agreements (SLA) rather than operate and maintain the entire network.

4.4 MVI Implementation Approach

4.4.1 Program Structure

To begin implementation of the Commonwealth AAM infrastructure development projects, the first logical step may be to seek out Public/Private partnerships for hardware and software technology for the creation of a backhaul data network and standardized end-user infrastructure access. This may also include engaging with AAM stakeholders to identify strategic locations throughout the state that may benefit from adding Wide-Area Low-Cost sensors for initial infrastructure network build-out.

As a pathway to adding additional inputs to the network, the Commonwealth may approve funding of AAM infrastructure projects on a case-by-case basis following a pre-defined process for identifying key success metrics such as validity of needs, viability of proposed solutions, and sustainment modeling. Creating a State AAM MVI funding approach to review and approve projects creates a system of checks and balances that distributes AAM infrastructure and funding where it is most needed, thus providing the highest return on investment through direct needs-based assessments. Approval and funding of AAM projects may take many forms, such as direct financial contribution, land or property use, access to Commonwealth resources, and ongoing support for operational approval.



4.4.2 Technology Partners

Technology providers may be sought as partners in developing the underlying components for MVI development, particularly the backhaul data network, system access and monitoring, and sensor integration efforts. This approach may provide the Commonwealth with a foundation on which to build out the additional "as needed" MVI components. As proposals are received and approved, their individual solutions may be integrated with the network to access shared resources. Examples of strategic partnerships can be seen in both the New York and North Dakota test sites, who leveraged the engineering capabilities of Thales to design an integration and operations solution[20][21].

4.4.3 Champion Operators, & Early Adopters

A public/private cost sharing effort for individual use cases may also contribute to hardware, software, and test and evaluation efforts for a mutually beneficial use case between a private entity and the Commonwealth. Technology and software providers have a vested interest in seeing their products gain regulatory approval and early adoption, and as such may be primed to form strategic partnerships for AAM infrastructure emplacement where state assets are applied to achieve the same goals. These partnerships will likely come from seeking out champion operators willing to utilize the technology for use cases of common interest, and jointly submit for approval for inclusion in the Commonwealth AAM infrastructure network. These partnerships and early use cases will set the groundwork for approval at both the State and Federal level for follow-on use cases that have similar needs and solutions sets, and set precedent for repeatable and cost effective AAM operations.

As an example, the North Carolina Department of Transportation was a participant in the FAA's Integration Pilot Program, which aimed to help integrate UAS into the National Airspace System. During the course of the program, the NCDOT partnered with Skydio, one of the largest U.S.-based drone makers, to pilot an autonomous UAS bridge inspection use case. This public-private partnership demonstrated how UAS may replace personnel in dangerous and time-consuming tasks surrounding highway infrastructure inspection without disrupting traffic. In 2020, the FAA awarded the NCDOT a waiver of authorization allowing them to operate UAS beyond visual line of sight while conducting bridge inspections, making them the first state transportation agency to receive such approval. Today, 28 state DOT's are using UAS technology to inspect bridges[22].

4.4.4 Industry Accelerators

GENIUS NY

The New York State Economic Development Team funds an annual UAS industry accelerator competition called GENIUS NY[23], with the goal of attracting and retaining companies in the State. The program began in 2017, and to date they've invested over $18 million in 32 companies from eight countries. Each year, a $3 million in investment is distributed to five winners. One grand prize winner receives $1 million investment, and four other teams each receive a $500,000 investment. Winners also receive support in the form of a monthly stipend in Phase I, free office space and amenities, workshops and events, and business training. They also have access to a dedicated group of executive advisers, industry mentors, and experts in recruiting, marketing, and fundraising, as well as numerous events and workshops, both within the local community and internationally. Additionally, GENIUS NY provides assistance in securing subsequent rounds of funding, which has resulted in $100 million in venture capital raised to date. There are several pre-

[20] https://www.auvsi.org/industry-news/nuair-alliance-and-thales-agree-collaborate-utm-research
[21] https://www.vantisuas.com/news/article?id=46
[22] https://www.skydio.com/blog/drones-transform-bridge-inspections#:~:text=These%20remotely%20controlled%20drones%20save,of%20traffic%20while%20in%20use.
[23] https://geniusny.com/

requisites and eligibility requirements, as well as post-award stipulation such as the requirement to operate their business in Central NY for at least one year.

AeroX

AeroX is a nonprofit organization of business, government and community partners focused on creating a national model ecosystem for advanced air mobility ecosystem and helping companies develop and leverage unmanned aircraft technologies. The organization supports North Carolina's continuing leadership in advancing AAM by serving as a testbed and model for AAM. A $5 million grant from the 2021 North Carolina General Assembly allows AeroX to design and develop an urban advanced air mobility system for the region and state. Their Board of Directors and Advisory Council include UAS industry business and community leaders, while strategic partners include a network of AAM innovators such as UAS manufacturers and operators, companies using UAS services, government agencies facilitating AAM advances, and support organizations aiding the startup, expansion and growth of partner companies. AeroX is sustained by memberships and grants from public and private sources.

4.4.5 Follow-On Use Cases

Champion Operators and Early Adopters may prove the viability of use cases through testing and validation of technology and concepts, thus defining a pathway for follow-on use cases with similar attributes. Once operational and regulatory precedence has been set, an outline or template can be created that may be used to gain similar use case approvals in other areas. Additionally, once MVI assets have been established for a particular use case, other use cases may present themselves that leverage the same infrastructure. For example, a medical delivery use case may be established in a particular location using medium-range MVI assets. Subsequently, a commercial UAS delivery company may be attracted to that same area and present a viable business case due to the presence of existing, validated AAM infrastructure.

4.4.6 Identification of Key Success Metrics

Success metrics for MVI projects may be defined through a combination of interconnected factors including the overall Commonwealth AAM strategy and the individual value propositions addressed by each use case. Inputs to the decision and approval process may include, but are not limited to:

- Validity of needs - number of people served, reduction in operating costs, lack of current or effective resources, enhancements to public safety or economic growth
- Viability of proposed solutions – effectiveness in solving problem, probability of buy-in and gaining community sentiment, likelihood of gaining regulatory and operational approvals
- Sustainment modeling – capital expenditures and ongoing support costs vs. expected ROI

While MVI development will focus on targeted risk mitigation of the AAM operation, localities must also consider whether the use case under consideration is both beneficial to the community and economically viable. For any given use case, a community can identify Metrics of Benefit and quantify the expected benefit of the planned AAM service – this can then be used to build an economic model to determine if the value derived from enabling AAM services is equivalent to the cost of operating the infrastructure. The table below includes examples of benefits metrics for various use case models.

Table 1:Metrics of Benefit for various AAM Use Cases

Metric \ Use Case	First Responder	Gov. & Utility Insp. & Monitoring	Logistics	Commercial
Reduced Dispatch	X	X		
Reduced Time to Dispatch	X	X		
Change in Modality	X	X	X	X
Harm Reduction	X	X	X	
Time & Cost Savings		X	X	X
Failure Prevention		X		
Post-Event Assessment Safety		X		
Commercial Value			X	X
Middle-Mile Value			X	

4.4.7 Funding Options

Funding options for MVI projects may be varied depending on contributing of factors, including but not limited to end user, location, stakeholders, and project scale/cost. As with all new infrastructure, funding may to come from a variety of potential sources. Given need and potential benefit, any MVI installation for a given community will likely need to leverage multiple sources of funding including but not limited to:

- **Direct Public Funding**, including funding upfront costs through Federal, State, Local and Private grants
- **Leverage Existing Local Assets**, including existing facilities, airports, and locally owned sensors and communications that can defray deployment costs and create re-use
- **Leverage Existing Commonwealth Assets**, including communications networks, sites, and services as well as personnel and expertise that can be leveraged for data and infrastructure services as public assets
- **Infrastructure as a Service Fees**, including financial contributions from both public and private operators that contribute to operations and sustainment in exchange for value added public data services such as those services that provide data to Detect and Avoid providers
- **Bonded Infrastructure Funding**, once a sustainable revenue stream for system operations and maintenance can be demonstrated, MVI can be considered “bonded infrastructure” which opens the door for localities to issue municipal Revenue Bonds and leverage public-private partnerships, similar to current infrastructure funding models such as stadiums and terminals.

5.0 Examples of Area Specific Challenges and Opportunities

Locations throughout the Commonwealth may have commonality in assets, geography, opportunities, and challenges, and therefore may benefit from similar MVI solutions to enable AAM use cases. This section highlights these various regions and their unique characteristics to provide examples of selection criteria for approval of near-term AAM infrastructure project funding. These example areas include broad grouping by overall regional characteristics or proximity to existing infrastructure, and by dynamic factors such as population density, economy, and emergency services usage. These geographical and socio-economic similarities and differences may be a contributing factor in approval of MVI projects, including what opportunities may exist as a result of MVI emplacement.

5.1 Location Characterization Criteria Discussion

With input from DOAV and other stakeholders, various regions across the state may be assessed for gaps in services, or according to other defined criteria, where autonomous aircraft may be best suited for serving the Commonwealth. In the context of this report these areas and use cases will be specific but are merely chosen as examples in order to form a comprehensive template for assessing future AAM needs. These examples use cases will then be iterated through the MAAP Safety Case Development Process in order to fully understand their scope, which will outline the process for understanding how the operations will be conducted in order to accurately gauge requirements and types of technologies that may be needed.

An area may be selected for MVI emplacement by assessing the existing needs or challenges for that region, or what business case may be made through implementation of AAM use cases. An area may be a single neighborhood, a specific demographic, or an overall bucket of deciding factors that aid in the decision-making process for MVI emplacement, including but not limited to:

- Emergency Frequency and Demand
- Transit Complexities
- Underutilized GA Airport
- Underserved Communities
  - Financially
  - Medically
  - Logistically
- Community Readiness
- AAM industry magnet area, i.e. potential to support multiple use cases with strong business cases for ROI

5.1.1 Regional (Coastal / Piedmont / Mountains)

Region-specific characteristics may help define problem sets unique to a specific geography, such as Coastal, Piedmont, and Mountains. In addition to geographic-centric features, each region also contains specific challenges based on population, industries, weather patterns, and other identifying factors that may generate challenges and corresponding use cases.

As an example, the Coastal Plains present challenges in terms of susceptibility to storm and flood damage, particularly during the Atlantic hurricane season. Post-storm assessment and aid response and coordination may be of concern in this region. Additionally, the Coastal Plains are home to wildlife sanctuaries and protected areas, making wildlife conservation efforts, specifically swamp, marsh, and ocean monitoring a unique challenge specific to this area. Ports and other logistics infrastructure distribution points are located along the Elizabeth River, with their own sets of challenges for issues such as monitoring, inspection, and security. Mountain regions have unique challenges associated with achieving sensor (communications and surveillance) viewsheds due to the undulating terrain. Other regions may experience their own sets of challenges such as wildfires, accessibility issues due to geographical features, issues related to highway infrastructure, and many other region-centric problem sets.

5.1.2 Population Density (Urban / Suburban / Rural)

Population density creates its own unique sets of challenges and may be an additional method for determining MVI placement in response to related use cases. Population density issues may be in the form of increased traffic or crime, as well as increased need for both public and private services such as first responder activities, medical delivery, and commercial delivery. Population density factors also include MVI cost and service calculations such as number of people served, number of services enabled, and cost per person/per service.

5.1.3 Economic Indicators or Incentive Areas (Opportunity Zones, GO Virginia Regions, etc.)

Economic indicators may also be a contributing factor in approval of MVI use cases, such as lack of industry, need for workforce training, unemployment rates, and other economic priorities that may be identified. Areas of consideration may include the number of jobs created, individuals or businesses that may benefit either directly or indirectly, and industry ecosystem that may develop as a result of MVI emplacement and use cases enabled. Community readiness may also be contributing factors, meaning the general public, local and national businesses, and local leaders have a positive reception for AAM use case implementation in a community.

5.1.4 Proximity to Existing Infrastructure

Proximity to existing infrastructure such as underutilized general aviation airports, rail, highway, and maritime shipping areas, and energy production and distribution infrastructure may also be used as part of the decision-making process for MVI project approval. For example, Virginia has 66 public use airports, of which 9 are commercial service and 57 are general aviation. Use cases that propose MVI to connect general aviation airports to commercial air services via AAM may use specific airport statistics as a viable MVI approval factor. Other examples include proximity to multiple transportation and shipping hubs that may all benefit from a single MVI emplacement or use cases that focus on protection of other critical infrastructure.

5.2 Example Area Descriptions with Needs and Opportunities

This section provides examples of area-specific challenges and near-term opportunities to demonstrate possible MVI use case selection and approval factors. These example areas will then be matched with solutions in an effort to demonstrate pairing of regional needs to corresponding AAM use cases.

5.2.1 Example Area 1 - Densely Populated Urban

The first example area is a densely populated urban city environment. Due to the number of inhabitants, first responder calls for police assistance are increasing. Law enforcement in certain high call volume areas are seeking solutions to better serve the public while maintaining a higher level of safety for both the officers and the citizens.

Area

Densely populated urban areas that receive a high volume of First Responder calls

5.2.2 Example Area 2 - Rural

The second example area is a low to medium population density rural area. Due to the distances between inhabitants and medical services, both EMS and hospital, response times for care are increasing. Local EMS and Hospital services are seeking solutions to better serve the community by decreasing response times for calls and increasing accessibility to services.

Area

Rural communities that are traditionally difficult to serve due to geographical challenges

5.2.3 Example Area 3 – Strategic Response Areas

The third example encompasses the entire state, spanning all regions, settings, and population densities. As better technology is developed, systems, tools, and methods of responding to natural and man-made disasters are becoming more efficient. To maintain the highest level of operational efficiency, State emergency response agencies are seeking updated solutions to manage on-demand emergency response activities.

Area

Pre-Positioned at strategic locations across the Commonwealth

5.2.4 Example Area 4 - Suburban

The fourth example area is a medium to high population density suburban area. Due to the number of inhabitants and retailers in the area, demand for consumer goods is increasing. In an effort to keep up with public demand, UAS delivery companies have formed partnerships with local and nationwide businesses and are seeking solutions to enable delivery of goods directly to consumers.

Area

Suburban residential areas and shopping centers

6.0 Use Case Discussion

Integration of UAS into business processes is becoming more common across multiple industries to aid in efficiency, safety, and cost savings by automating dangerous and/or time-consuming tasks. From responding to emergencies, to inspecting hundreds of miles of linear infrastructure, to providing last-mile delivery services, this section provides an overview of several high priority UAS use cases and how they can address a variety of challenges.

6.1 Drone as a First Responder (DFR)

6.1.1 Police

911 Call Response – Added support to police operations by providing critical information during calls for emergency services and criminal investigations.

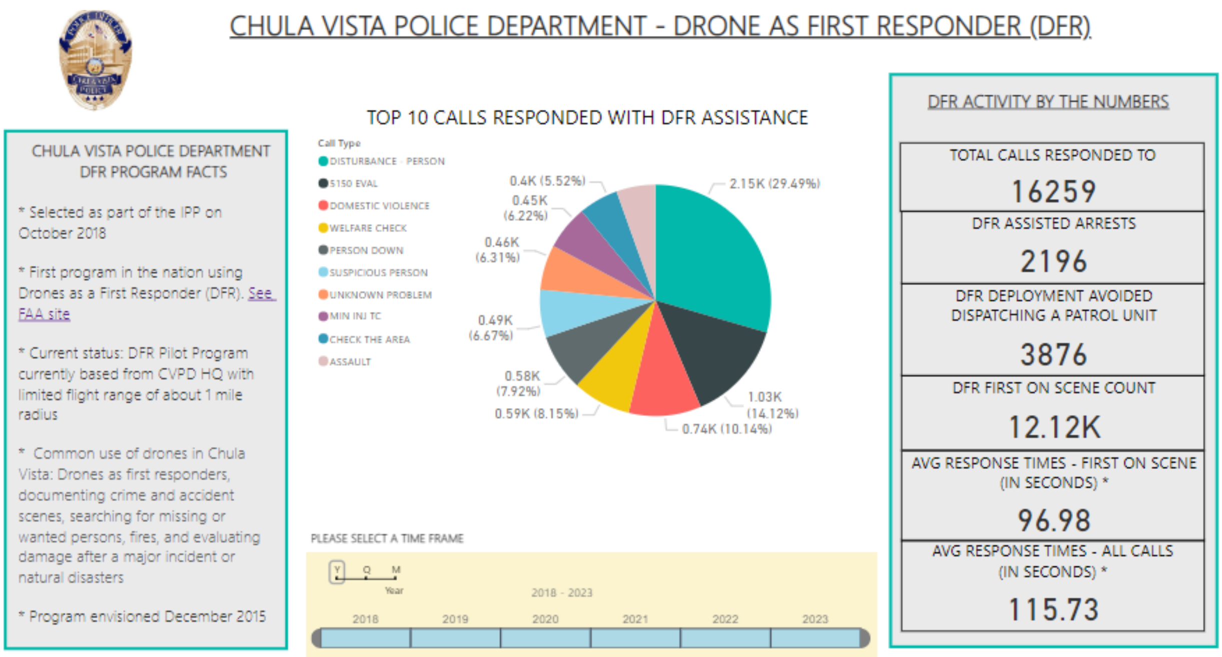


Figure 28: Drone-Related police activity dashboard form the Chula Vista police department depicting DFR operational statistics. Source: Chula Vista Police Department - https://www.chulavistaca.gov/departments/police-department/programs/uas-drone-program

Search and Rescue – UAS with cameras and thermal imaging sensors used to search for missing persons or locate victims in difficult-to-reach locations

Crime scene – UAS with high-resolution cameras used to capture images and video of crime scenes from multiple angles to aid in suspect location and movement as well as reconstruction of the scene to gather evidence

Traffic & Accidents – UAS used to monitor traffic and identify congestion aiding in quicker response times; UAS used to map accident scenes to aid in restoring traffic; UAS used to recreate accident scenes to aid in determining cause and identifying contributing factors

Crowd Safety – UAS with cameras and speakers used to monitor large crowds and provide real-time updates to resources on the ground to include early detection of potential threats

Tactical Ops – UAS with cameras providing "birds-eye" view of hostage situations, SWAT operations, or stand-offs while gathering real-time intelligence; small UAS used within interior of buildings to aid in clearing rooms prior to ingress.

6.1.2 Fire

Firefighting – UAS with thermal imaging sensors used to detect hotspots and areas of high heat in real-time to aid in risk assessment

Search and Rescue - UAS with cameras and thermal imaging sensors used to search for missing persons or locate victims in difficult-to-reach locations

Pre-fire Planning – UAS with high-resolution cameras used to capture detailed imaging of building and structures, providing valuable data about potential hazards and access points

6.1.3 EMS

Life-saving Medical Supply Delivery – UAS integrated with delivery technology used to supply life-saving items like AED defibrillator machines or epinephrine auto-injectors (EpiPen) to austere environments; re-supply of consumed items in a large-casualty event

Additional insights and information regarding Drone as a First Responder programs can be found in a study published by MITRE[24]

6.2 Government & Utility Inspection & Monitoring

6.2.1 Wildlife

Wildlife Conservation – UAS with cameras used to monitor wildlife populations, track migrations, observe habitat health and changes over time

6.2.2 Post-WX event

Severe Weather Event Environmental Assessment – UAS with cameras used to assess and map areas affected by floods, landslides, volcanic eruptions, and earthquakes to aid in response and evacuations

Severe Weather Event Infrastructure Assessment – UAS with cameras used to assess damage to buildings, infrastructure, roads, and bridges after a severe weather event to aid accurate and prompt documentation for insurance claims

6.2.3 Infrastructure

Infrastructure Inspection – UAS with cameras used to assess condition and functionality of infrastructure to aid in preventative maintenance and in repair efforts

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[24] https://www.mitre.org/sites/default/files/2023-08/PR-23-2677-DFR-Drone-First-Responder-Programs.pdf

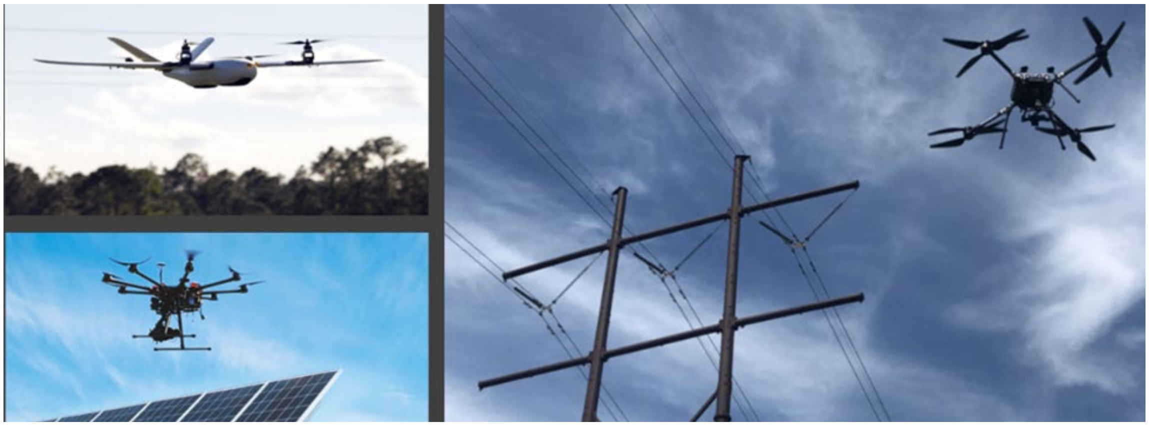


Figure 29: UAS for Utility Inspection. Source: Dominion Energy. https://www.dominionenergy.com/our-stories/unmanned-aerial-inspections

6.2.4 **Traffic/Event**

Large Event Traffic Support – UAS with cameras used to assist ground personnel in traffic routing and parking for large-scale events such as sporting events or entertainment festivals

6.2.5 **Security**

Facility Security – UAS with camera and thermal imaging sensors used to conduct security sweeps of facilities to aid in detecting unauthorized access and malevolent actions by bad actors

6.3 Delivery

6.3.1 **Commercial**

Commercial Delivery – UAS integrated with delivery technology used to delivery small consumer items which is faster and more efficient than ground delivery and decreases the carbon impact on the environment as well as risk to human conducting ground-based delivery via roadways

Figure 30:Example of commercial delivery service utilizing autonomous UAS. Source: wing - https://wing.com/

6.3.2 Medical

Medical Supply Delivery – UAS integrated with delivery technology used to deliver small loads of medical equipment and supplies (tourniquets, dressings, analgesics, blood products) to underserved and remote locations

6.3.3 B2B

B2B Middle-Mile Logistics – medium to large UAS integrated with cargo capacity used to deliver cargo loads from business to business such as seaports and distribution centers.

6.4 Technology Validation and Training Sites

6.4.1 sUAS

sUAS Research and Development – small UAS used to further the research and development of integrating drones into the National Airspace System by safely and reliably flying beyond the visual line of sight of the operator, and by safely and reliably flying over people and moving vehicles; research and development of detect and avoid technology and command and control technology; generate data used by industry and regulators on routine use of drones.

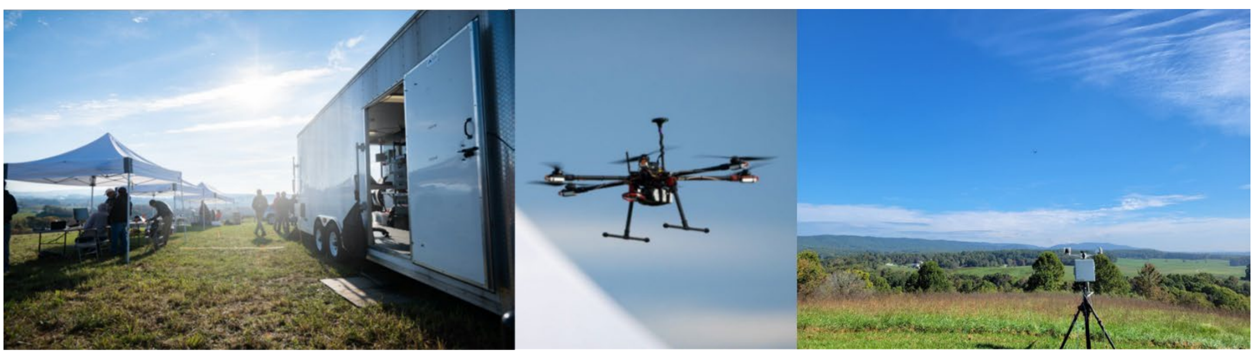


Figure 31: Virginia Tech's Mid-Atlantic Aviation Partnership FAA designated UAS Test Site. Source: MAAP https://maap.ictas.vt.edu/

6.4.2 Large UAS & UAM

Urban Air Mobility (UAM) Research, Development, and Operation– large UAS used to further the research and development of advanced air mobility (transporting people and goods between local, regional, intraregional, and urban locations not previously served or underserved by aviation using innovative aircraft, technology, infrastructure, and operations) with a focus on the subset of urban air mobility with the support of a cooperative operating environment which complements traditional Air Traffic Services

6.4.3 Corridors

UTM Drone Corridor – UAS integrated with DAA and C2 technology enabling true BVLOS operations and generating data that will inform the industry and regulators on routine commercial use of drones

6.4.4 Workforce Training

UAS Training – UAS used to meet the demand for drone skills, including pilot and maintenance technician, through training and education

UAS in STEM – UAS used by educators to develop vocational training programs and skills in the unmanned aerial system industry

Figure 32:Students at the Virginia Tech Drone Camp, in collaboration with the Mid-Atlantic Aviation Partnership FAA designated UAS Test Site, show the drones they built as part of program to explore STEM careers. Source: Virginia Tech. - https://news.vt.edu/articles/2022/08/ictas-dronecamp-2022.html

6.5 Other Commercial Services

6.5.1 Survey

Aerial Survey – UAS with cameras used to capture aerial photogrammetry which is used to create 3D maps with GPS coordinates and accurate measurements, to aid in survey of construction sites, mining and aggregate sites, and waste management sites; to aid in production of floodplain mapping; to aid in production of accurate, 3D topographic mapping

6.5.2 Agricultural

Agricultural Aerial Support – UAS with cameras used to assess crop needs such as irrigation and nutrients to include spray applications of herbicides, insecticides, fertilizers, and seed; monitor crop growth and yield optimization

6.5.3 Vertiports

UAS and Vertiports – UAS used to and from vertiports enabling urban air mobility and facilitating the movement of people and goods more rapidly and efficiently than traditional transport infrastructures

6.5.4 Urban Air Mobility (UAM)

UAS and UAM – large UAS used to transport people and goods between urban locations not previously served or underserved by aviation using innovative aircraft, technology, infrastructure, and operations and supported by a cooperative operating environment which complements traditional Air Traffic Services

Figure 33: Depiction of Urban Air Mobility via eVTOL (electric Vertical takeoff and landing) vehicles, landing on and departing from dedicated infrastructure points (vertiports).Source: NASA - https://technology.nasa.gov/patent/TOP2-298.

Table 2:Example Use Case Selection Matrix organized by overreaching AAM operational heading. For example, a DFR use case may be applicable to a number of nuanced AAM initiatives, while a Delivery use case may range from consumer goods to commercial cargo.

DFR	Gov./Utility Insp. & Monitoring	Delivery	Test Ranges	Commercial Services
Police	Wildlife monitoring	Commercial	sUAS	Survey
Fire	Post-WX event	Medical	Large UA/UAM	Agriculture
EMS	Infrastructure Insp	B2B/Cargo	Corridors	Vertiports
Public Safety	Traffic/Event	Public/Private	Workforce Training	UAM

7.0 Method for Defining Use Case Operational Context

The ConOps development process starts with an understanding of the use case mission objectives, operational description, and requirements definition. Any technologies that are desired or are mandatory aspects of the operation are considered technology "inputs" as the operation is described, and requirements are defined. The ConOps fully characterizes the entire operation and is then used as an input to the risk assessment process. The ConOps discussions for each Use Case contain three sections; Mission Objectives, Operational Description, and Requirements Definition.

- The Mission Objectives section defines the "why" of the proposed use case in terms of what business objectives or end goals are being pursued.
- The Operational Description section defines the vision for each use case in terms of its end use operations and workflows. This section will explore the basic constructs of each of the example use cases in terms of initial concept and will help define how to the Objectives will be accomplished.
- The Requirements Definition section defines the capability a technology, service, or product must bring in order to complete the mission objectives and fulfill the initial operational description. This section will explore basic functional elements and will help clarify what is needed to realize the Operational Description.

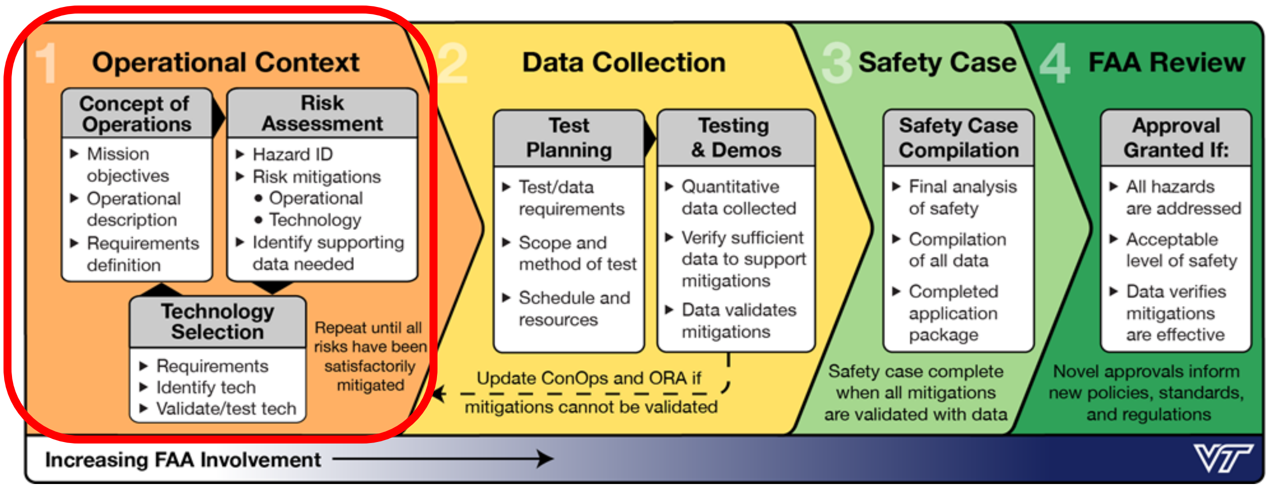


Figure 34: Phase 1 of the MAAP Safety Case Development Process.

7.1 Use Case and Needs Pairing

The MVI approach to AAM implementation focuses on addressing specific area needs and identifying solutions through targeted use case development. Section 5 discussed examples of the unique challenges and opportunities across different regions of the Commonwealth, while Section 6 provided an overview of AAM solution sets. This section aims to show examples of how area needs may be met by matching them with appropriate near-term use cases, and how those use cases may be operationalized through the safety case development process.

7.2 Example Operational Context for Use Case 1 - Densely Populated Urban & DFR

Area

Densely populated urban areas that receive a high volume of First Responder calls

Use Case

Drone as a First Responder

7.2.1 Mission Objectives

In this example, a police precinct has identified a need for situational awareness tools to aid in both officer and citizen safety by providing pre-intervention information to guide on-scene activities. With a high number of emergency services calls, efficiency and safety may be increased by providing first-responders with as much information on the situation as possible before they arrive in order to affect the most positive outcome. The drone as a first responder use case would position a UAS to provide critical information by arriving first on scene and transmitting data to relevant persons so the appropriate response may be applied in terms of scale, tactics, and resources.

7.2.2 Operational Description

A police precinct has identified specific high-volume call areas that require additional support resources. In response, a UAS equipped with a live-stream video and audio package will be used to aid responders in on-scene decision making. The UAS will be deployed from a central location, likely the roof of the police precinct building and sent to the incident location. The UAS will transmit data back to the precinct to better inform command and responding units of the situation before they arrive. Once officers arrive on scene, the UAS may be used as an additional safety backup for continued situational awareness. After the situation is resolved the UAS will then return to the takeoff location. Multiple UASs may be used as a fleet to respond to multiple incidents simultaneously, with pilot and oversite activities handled from an operations command station within the precinct building.

7.2.3 Requirements Definition

In order to effectively operate a drone as a first responder program, the appropriate technology, including both hardware and software must be selected that satisfies the mission objectives and operational description. For this use case, a UAS with adequate range and endurance, equipped with a sufficient Intelligence, Surveillance, Reconnaissance (ISR) payload package must be selected. In addition, mission planning, flight execution, and fleet management software will be needed to control the UAS and receive the data it transmits, as well as manage resources, including maintenance, metrics, historical data, and evidence collection. Additional hardware will include workstations for Remote Pilot in Command (RPIC) and other users, and airspace surveillance and communications systems with sufficient coverage of the intended operations areas. For a small, individual, or isolated flight areas, a single airspace surveillance sensor may be used to supplement Visual Line of Sight (VLOS) operations to enable incidental BVLOS.

7.3 Example Operational Context for Use Case 2 – Rural & Medical Delivery

Area

Rural communities that are traditionally difficult to serve due to geographical challenges

Use Case

Medical Delivery (emergency and non-emergency)

7.3.1 Mission Objectives

In this example, the local EMS station seeks to identify a means of expediting both emergency and non-emergency services to residents that traditionally see higher response times due to the large geographical service area. In this type rural setting, people and resources are spread out to an extent that outlying areas may have to wait for life-saving services that may be administered by non-emergency response persons, such as AED, Narcan, or EPI. For these type cases, an expedited means of delivery that precedes an in-person EMS response may result in a more positive outcome. In non-emergency cases, residents in some areas may require certain prescriptions or medical supplies, however due to the geographic distance, these residents, specifically the elderly or disabled, may not receive the services they need in a timely manner. For these type cases, direct door to door delivery of supplies or medication may result in a higher quality of care. The medical delivery use case would position a UAS to provide both critical and non-critical care by expediting delivery of certain devices, medications, and supplies to residents much quicker than in-person response times, resulting in a higher level of care over traditional methods.

7.3.2 Operational Description

An EMS station has identified trends in services requests in outlying areas that require shorter response times. To effect this change, a UAS equipped with a delivery mechanism will be used to send the required equipment or medication to the call location ahead of EMS arrival to help ensure patients receive time sensitive treatment in a timeframe that ensures higher success rates. The UAS will be deployed from a central location, likely the roof of the EMS building, and sent to the patient's location. The UAS will deliver the required device or medication, and then return to the takeoff location. Multiple UASs may be used as a fleet to respond to multiple incidents simultaneously, with pilot and oversite activities handled from an operations command station within the EMS station.

7.3.3 Requirements Definition

In order to effectively operate a UAS medical delivery program, the appropriate technology, including both hardware and software must be selected that satisfies the mission objectives and operational description. For this use case, a UAS with adequate endurance and payload capacity, and equipped with a package delivery mechanism must be selected. Like the DFR use case, mission planning, flight execution, and fleet management software will be needed to control and manage the operations, with the addition of any use case specific features that may be identified. Additional hardware will also include workstations for Remote Pilot in Command (RPIC) and other users, and airspace surveillance and communications systems with sufficient coverage of the intended operations areas. For this size area, a single airspace surveillance sensor may be used to enable BVLOS operations.

7.4 Example Operational Context for Use Case 3 – Strategic Response areas & On-Demand

7.4.1 Mission Objectives

In this example, State Emergency Services agencies have identified a need for situational awareness tools to aid in responding to a variety of natural and man-made disasters that may occur across the Commonwealth. With diverse geography ranging from coastal to mountains, and hundreds of miles of interstates running through it, Virginia has the potential for major weather events, wildfires, traffic incidents, and other large-scale emergency events. Mobile command centers with dedicated UAS and AAM infrastructure assets would be used to collect and distribute critical real-time information across multiple State agencies to aid in efficiency of response. Due to the widely diverse geography of the state, these mobile command centers may be pre-positioned at key strategic locations in order to provide the quickest response times. When not in use by the State, these AAM assess may also be used by Local government agencies to supplement immature systems such as traffic monitoring and rerouting, Police actions, and other localized, smaller scale events.

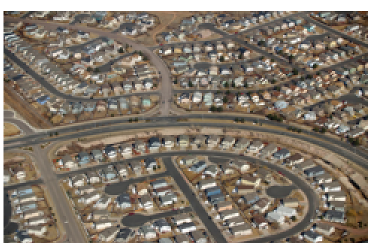
7.4.2 Operational Description

State emergency response agencies have identified the need for increased information gathering and coordination tools to better serve communities impacted by natural and man-made disasters. In response, mobile command centers equipped with communications and airspace surveillance systems will be deployed to emergency response areas. These mobile command centers will also be equipped with complimentary UAS capable of gathering the appropriate information. The UAS will be deployed from the mobile command center location and used to surveil the area, transmitting data back to the mobile command center where it may be shared live with other stakeholders via the AAM backhaul network.

7.4.3 Requirements Definition

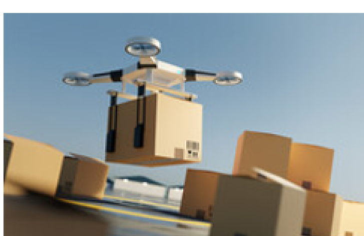
A command center vehicle or trailer capable of housing the required technology, including airspace surveillance sensors, communications antennas, weather sensing equipment, and interior workstations and equipment storage areas would be needed to support on-demand operations at locations across the Commonwealth. Onboard equipment may include computers, servers, networking equipment, internal and external displays, and generators. Additionally, a UAS capable of vertical takeoff and landing, long endurance flight, and the ability to quickly swap payloads in response to mission requirements, such as video, camera, LiDAR, multispectral, etc. will be a complimentary piece of the overall requirements.

7.5 Example Operational Context for Use Case 4 – Suburban & Commercial Delivery



Area

Suburban residential areas and shopping centers



Use Case

Multiple commercial operations

7.5.1 Mission Objectives

In this example, a UAS delivery company has identified an area that is commercially viable for expanding its services into, including partnerships with local and national retailers to deliver goods to their customers via drone. Community outreach activities and surveys indicate an overwhelmingly positive response to drone delivery services and combined with pilot program and limited services model successes in other communities, a full-scale rollout is proposed that maximizes the potentials of both business case and community benefits. A fully operational drone delivery service would bolster the local economy and be a magnet for follow-on industry use cases by enabling long-range (10mi. +/-) UAS autonomous operations within a large airspace surveillance volume.

7.5.2 Operational Description

A commercial drone delivery company has identified a viable business case for partnerships with local and national retailers to deliver goods direct to customer's homes. This service will entail a large fleet of autonomous UAS picking up and delivering consumer goods across a wide area of residential and shopping locations. The UAS will be deployed and managed from a central location and sent on-request to various businesses to retrieve pre-packaged goods. After retrieval, the UAS will fly an automated route to the delivery location, and then either return to the takeoff location or proceed to another pickup and delivery route. Multiple UAS will be operating simultaneously to serve a wide range of businesses and customers. The long-range airspace surveillance and associated AAM infrastructure is expected to attract additional users and use cases, including other delivery services, survey, agriculture, and other commercial services.

7.5.3 Requirements Definition

For this use case, wide area airspace surveillance sensors would be needed to support BVLOS flight, which is a key enabler for making these type operations commercially viable. Since these operations would occur across a large area, operators will require additional, live data feeds for situational awareness, including localized weather, FAA airspace status data, and other time sensitive information from other federal, State, and Local agencies. In addition, due to the expected volume of users including follow-on use cases, a means of UAS-to-UAS separation will be needed to ensure autonomous flight routes are deconflicted, both internal and external to a specific operation. Finally, due to line-of-sight issues for BVLOS flights combined with frequency congestion and interference concerns, a licensed band communications network would be required to endure security of the Command and Control (C2) links between UAS and command stations. Placement options for the required infrastructure elements may be secure locations similar to cell tower sites, with assets elevated to provide adequate viewshed of the operational area

8.0 Risk Assessment

8.1 Risk Areas

Phase one of the MAAP safety case development process includes a formal operational risk assessment. To perform the risk assessment, risk areas for the ConOps are identified and scored according to probability of occurrence and potential severity. For each of the three example use cases, air and ground risks were considered separately due to the complexity and specific details that pertain to each use case.

8.1.1 Air Risk

Air Risk refers to the potential for the UA to cause harm to persons or property in the air, more specifically, proximity to other aircraft that falls below established separation minima. All use cases involving aircraft navigating the national airspace will incur certain risks inherent to airborne operations. The example use cases in this report will share some level of airborne risk, yet each use case may have hazards unique to their specific operation. MAAP's safety case development process looks to identify these common and unique hazards in the Mid-Air category, score the level of risk the hazards present, and apply mitigations to help lower the overall risk to an acceptable level.

Some of the common air risks include, but are not limited to:

- UA colliding with crewed traffic (including commercial, general, and military traffic)
- Critical failures, including C2 and GPS failures, leading to accidents
- Bird strikes

8.1.2 Ground Risk

Ground Risk refers to the potential for the UA to cause harm to non-participants or property on the ground underlying the intended operational area. Similar to the air risk category above, multiple hazards may be presented for ground risk that are unique to the example use case. MAAP's safety case development process looks to identify these hazards in the Casualty and Property category, score the level of risk the hazards present, and apply mitigations to help lower the overall risk to an acceptable level.

Some of the common ground risks include, but are not limited to:

- Low flying UAs colliding with ground-based infrastructure
- Landing in non-cleared areas
- Critical failures leading to emergency landings in non-cleared areas

8.1.3 Security Risk

Security risk may refer to the integrity of the command and control (C2) link between operator and UA, and the encryption and security methods in place to protect the flow of data. Traditionally, UA have utilized unlicensed spectrum for C2, which does not protect against interference from outside sources. The FAA has recently determined that while conducting operations in controlled airspace or BVLOS, a licensed band C2 may be required in order to mitigate interference and tampering (AC 107-2A B.6.1.2).

Security risk may also refer to the ability to ascertain the identification, operator, and intent of any UAS that may pose a threat to people, property, or security. Knowing the identification of a UA, the location of the pilot and/or control station, and any other pertinent information may assist law enforcement and other governmental and/or security personnel in maintaining the safety of the NAS and the people and property under which a UAS may be operating. 14 CFR Part 89 defines the rules for Remote ID and is discussed in more detail in Section 11.

Some of the common security risks include, but are not limited to:

- Lost link
- Fly away
- Inadvertent flight into unauthorized areas

8.2 Operational Risk Assessment (ORA)

The example use cases were examined to identify initial broad area risks inherent to the type operations proposed. The mission objectives and operational descriptions were reviewed to identify hazards in accordance with the FAA 8040.6 Unmanned Aircraft Systems Safety Risk Management Policy[25], which establishes the safety review process for UAS and provides a generalized list of common hazards and possible mitigations. Each risk was scored according to its potential severity and likelihood for Mid-Air Collision, Casualty, and Property Damage, and assigned an unmitigated risk value for Severity (Table 3) and Likelihood (Table 4) per FAA Order 8040.6, along with the accompanying UAS operational Risk Matrix (Table 5) that combines the

[25] https://www.faa.gov/documentLibrary/media/Order/FAA_Order_8040.6.pdf

Severity and Likelihood definitions with a scoring system similar to the ASTM Standard Practice for Operational Risk Assessment of sUAS. The y-axis categorizes the likelihood that a particular hazard will occur, and the x-axis categorizes the impact or level of danger a particular hazard will convey.

MAAP's ORA process includes input from subject matter experts (SME) across safety, flight operations, engineering, and safety case development disciplines all collaborating to identify hazards that are relevant to each use case. Once the hazards are identified, the level of risk for each hazard is determined through research studies and SME experience. The level of risk is then compared to the FAA Order 8040.6 likelihood and severity definitions, and then transplanted to the MAAP UAS Operational Risk Matrix. The resultant score determines the level of risk (high, medium, low), which can be accepted as is for the operation, or mitigation strategies can be researched to lower risk to an acceptable level.

Table 3: FAA Order 8040.6 Severity Definitions

Minimal **5**	**Minor** **4**	**Major** **3**	**Hazardous** **2**	**Catastrophic** **1**
Negligible safety effect	- Physical discomfort to persons Slight damage to aircraft/vehicle	Physical distress or injuries to persons - Substantial damage to aircraft/vehicle	Multiple serious injuries; fatal injury to a relatively small number of persons (one or two); or a hull loss without fatalities	Multiple fatalities (or fatality to all on board) usually with the loss of aircraft/vehicle

Table 4: FAA Order 8040.6 Likelihood Definitions

	Qualitative	**Quantitative – Time/Calendar-based Occurrences Domain-wide/System-wide**
Frequent A	Expected to occur routinely	Expected to occur more than 100 times per year (or more than approximately 10 times a month)
Probable B	Expected to occur often	Expected to occur between 10 and 100 times per year (or approximately 1-10 times a month)
Remote C	Expected to occur infrequently	Expected to occur one time every 1 month to 1 year
Extremely Remote D	Expected to occur rarely	Expected to occur one time every 1 to 10 years
Extremely Improbable E	Unlikely to occur, but not impossible	Expected to occur less than one time every 10 years

Table 5: MAAP UAS Operational Risk Matrix

Virginia Tech UAS Operational Risk Matrix					
Severity / Likelihood	Minimal	Minor	Major	Hazardous	Catastrophic
Frequent	5n	10a	15a	20a	25n
Probable	4a	8a	12a	16n	20b
Remote	3a	6a	9n	12b	15b
Ext Remote	2a	4b	6b	8b	14 * / 10b
Improbable	1n	2b	3b	4c	8c
		High Risk 13.1-25.0 Medium Risk 7.1-13.0 Low Risk 1.0-7.0		*Single Point or Common Cause Failures = Red / 14	

8.3 Risks Associated with Example Use Cases

In addition to the generalized Air, Ground, and Security risks listed in Section 8.1 that may be inherent to most UAS operations, the hazards identified below are more specific based on the use case information. Once these hazards were identified, they were assigned a score from the MAAP UAS Operational Risk Matrix in Table 5 based on the perceived likelihood and severity determined by the MAAP SMEs. Each hazard was scored individually, and the worst-case scenario was leveraged in determining expected frequency and severity. These hazards will require research into strategic mitigations to lessen the scored risk to an acceptable level. Most hazards in the High and Medium risk category were scored with a likelihood between probable and extremely remote and a severity between major and catastrophic. While required mitigation strategies will need to be researched to lower these risks to an acceptable level, the mitigations developed for the higher-risk hazards may be effective in lowering moderate risks as an added residual value. All other identified hazards that were not scored as high or medium risk fall into the low-risk category. These low-risk hazards do not need to be mitigated further, but the mitigations developed for the hazards deemed high or medium risk may impact the level of risk and should therefore be considered.

8.3.1 Risk Assessment for Example Use Case 1

The risks associated with Drone as a First Responder use cases present exposure to all three risk categories due to the nature of the urban areas they will likely operate in. These areas tend to have increased air traffic due to the larger population, leading to an increase in traditional aviation flights and therefore greater exposure to non-participating air traffic.

For Casualty and Property risk, population density in urban areas contributes to the likelihood that any unforeseen failures may result in contact with a person or their property, especially in emergency situations. Additionally, this use case requires flight paths to be developed in real-time versus utilizing pre-planned routes, thus introducing an additional level of risk inherent to short-term planning.

8.3.2 Risk Assessment for Example Use Case 2

The risks associated with UAS Medical Delivery operations may vary depending on location and implementation specifics. For rural locations, some risk areas would be minimized compared to urban and suburban areas due to a lower density of population, buildings, and obstructions.

The medical delivery package would be light weight to allow for minimal interference with the operation and flight of the UA, however adding an attached package does increase the Property and Casualty risks risk if the package were to fall off the UA.

The highest scored hazard for this use case relates to the “on demand”, or ad-hoc, flight planning. Similar to a DFR use case, an emergency situation cannot be predicted, resulting in real-time flight planning utilizing data supplied from a provider to ensure they are able to fly at a safe height to clear all obstacles. Additionally, any off-nominal or emergency landings during these flights will have an increased risk due to uncertainty surrounding the flight path.

8.3.3 Risk Assessment for Example Use Case 3

The risks associated with Mobile, On-Demand UAS Emergency Response operations revolve around the changing and varied population, terrain, and environmental conditions that it may encounter depending on the region it is serving and the situation it is responding to.

For the Mid-Air Collision risk category, difficulties with C2 link, such as LTE, will vary based on line of sight, terrain, vegetation density, and other variables such as viewshed and takeoff/landing locations. Prepositioning may help mitigate this hazard, but the amount of preplanning will be variable depending on required response time. An additional Mid-Air Collision risk is the potential for increased low-level traditional aircraft flights operating in a confined emergency area.

For Casualty and Property risks, rapidly changing weather or other environmental conditions such as wind gusts or smoke may negatively affect the UA, leading to an increased risk of failure or loss of control.

8.3.4 Risk Assessment for Example Use Case 4

UAS commercial delivery has a fair number of advantages compared to the other use cases, as the routes can be more refined and better planned compared to the "ad-hoc" nature of emergency flights. The operations area can be surveyed before service begins to provide input on factors that may affect the flights, such as C2 limitations, terrain and obstructions, and expected delivery locations. For Casualty and Property risk areas, packages attached to the UA may pose a risk to persons and property if they fall off the UA depending on package size and shape. Shippable items may force the user to use larger size packaging materials which can have a greater effect on the endurance, flight characteristics, and weight and balance. These changes can potentially lead to unstable flight for the UA. Finally, the delivery portion of the flight will need to be considered as dropping a package with a person or property nearby could lead to an impact causing damage and distress.

Table 6: Highest scored unmitigated risks for each Example Use Case

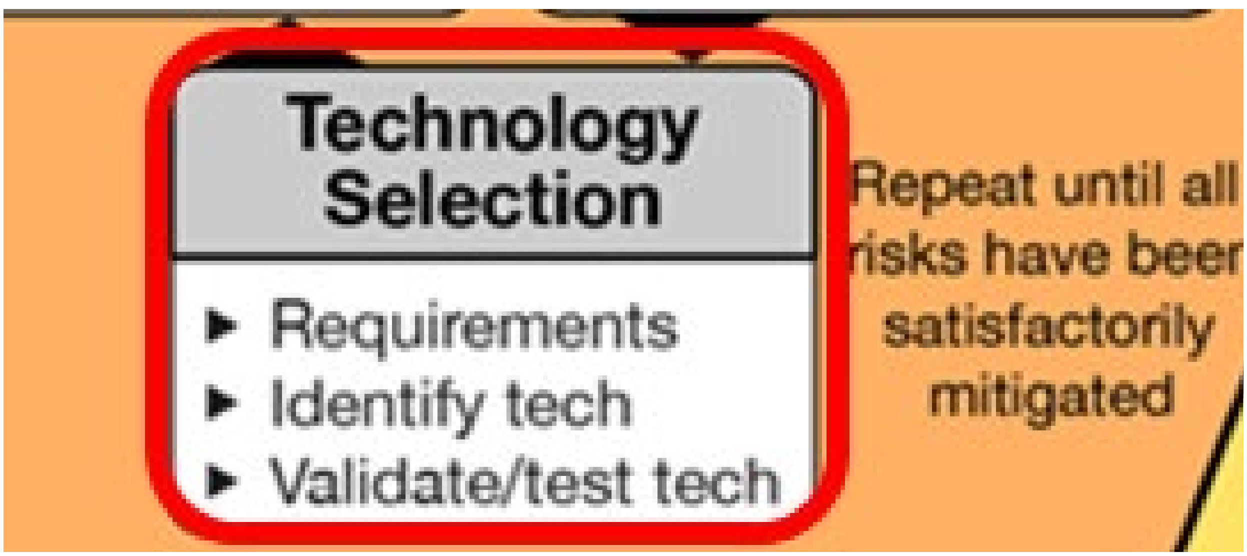
Use Case	Risk Description	Risk Category	Score
DFR	UA flight path will need to be developed in real time leading to possibility of colliding with terrain or property.	Mid-Air / Property	12b/9n
	Increased likelihood of a collision with person or property due to increased frequency of flying in populated areas	Casualty / Property	9n/6a
	Increased likelihood of a mid-air collision due to increased air traffic near urban areas	Mid-Air	12a
Medical Delivery	Package falls off UA and lands on person/property	Casualty / Property	6b/4b
	UA flies into terrain due to limited area data	Casualty / Property	12b/9n
	Off-nominal landings pose a higher risk with potential "on demand" flights	Casualty / Property	9n
On-Demand Emergency	Weak C2 link or service leads to a fly-away	Mid-Air Collision	9n
	Flying in deteriorating weather leads to the UA having a failure in-air	Casualty / Property	12b / 9n
	Flying in an emergency area can lead to an increase in traditional aviation traffic (search and rescue, disaster response, etc.) resulting in a mid-air collision	Mid-Air Collision	12a
Commercial Delivery	Package falls off UA and lands on person/property	Casualty / Property	6b/4b
	Person / Property is located directly under UA package drop-off point	Casualty / Property	9n/6a
	Package dimensions and weight may alter the weight and balance of the UA and potentially unstable flight.	Casualty / Property	12a / 8a

9.0 Technology Selection

In an AAM use case implementation scenario, technology would be employed as a mitigation element for addressing identified safety risks and operational requirements. Within the MVI methodology, the technology deployment may range from an overarching strategy to mitigate risks across several different use cases, to a single use case specific application. At either end of the spectrum, the technology choices would be appropriate for the intended operations they support and scaled accordingly.

9.1 Technology

A technology selection process must be conducted to determine all of the specific components necessary to effectively meet each of the different use cases. Many technologies will cross over between use cases, while others will be specific to the example Use Cases. The concept of operations influences the risk assessment, which in turn influences the technology selection process in phase one of the MAAP safety case development process. The technology selection will then circle back to influence the concept of operations in this first phase. Once all the risks have been considered and mitigated to an acceptable level, the phase is complete.



9.1.1 Airspace Surveillance

Both crewed and uncrewed aircraft operating in the US national airspace must “see and avoid” other aircraft. Traditionally, UAS have met this requirement by staying within visual line of sight (VLOS), where the aircraft and surrounding airspace can be directly viewed by the pilot in command and/or visual observers. To fly beyond visual line of sight (BVLOS), technology is employed to meet the “see and avoid” requirement.

Detect and Avoid (DAA) technology refers to two separate but complimentary concepts employed to meet the see and avoid requirements while operating BVLOS. The “see”, or detect portion uses either ground based or airborne sensors to detect other aircraft, thus providing situational awareness alerting where human eyes cannot see. The avoid portion then uses a manual or automated avoidance logic in response to a detection, which ensures safe separation from other aircraft. In the context of MVI, a ground-based detection sensor will likely be utilized. Given the wide variety of UAS and methods of accomplishing the avoidance portion in response to a detection alert, the onus for the avoidance strategy will be on the individual end users.

9.1.1.1 Cooperative vs. Non-Cooperative

A large aspect of airspace surveillance sensor design and performance is the distinction between cooperative and non-cooperative intruders. A sensor designed to detect cooperative intruders relies on information being actively transmitted by the intruder. A sensor designed to detect non-cooperative intruders does not rely on intruder supplied information, and detects aircraft by other means. Typically, cooperative aircraft will be actively transmitting information about their call sign, type aircraft, position, altitude, and airspeed via transponder or Automatic Dependent Surveillance-Broadcast (ADS-B), while non-cooperative aircraft will not be actively transmitting any of this information.

As of January 1, 2020, the FAA mandated that ADS-B out is required to operate in:

- Class A, B, and C airspace.
- Above the ceiling and within the lateral boundaries of a Class B or Class C airspace area upward to 10,000 feet MSL.
- Class E airspace within the 48 contiguous states and the District of Columbia at and above 10,000 feet MSL, excluding the airspace at and below 2,500 feet above the surface.
- Class E airspace at and above 3,000 feet MSL over the Gulf of Mexico from the coastline of the United States out to 12 nautical miles.
- Within 30 nautical miles of those airports identified in 14 CFR part 91, Appendix D. Otherwise known as the Mode C veil.

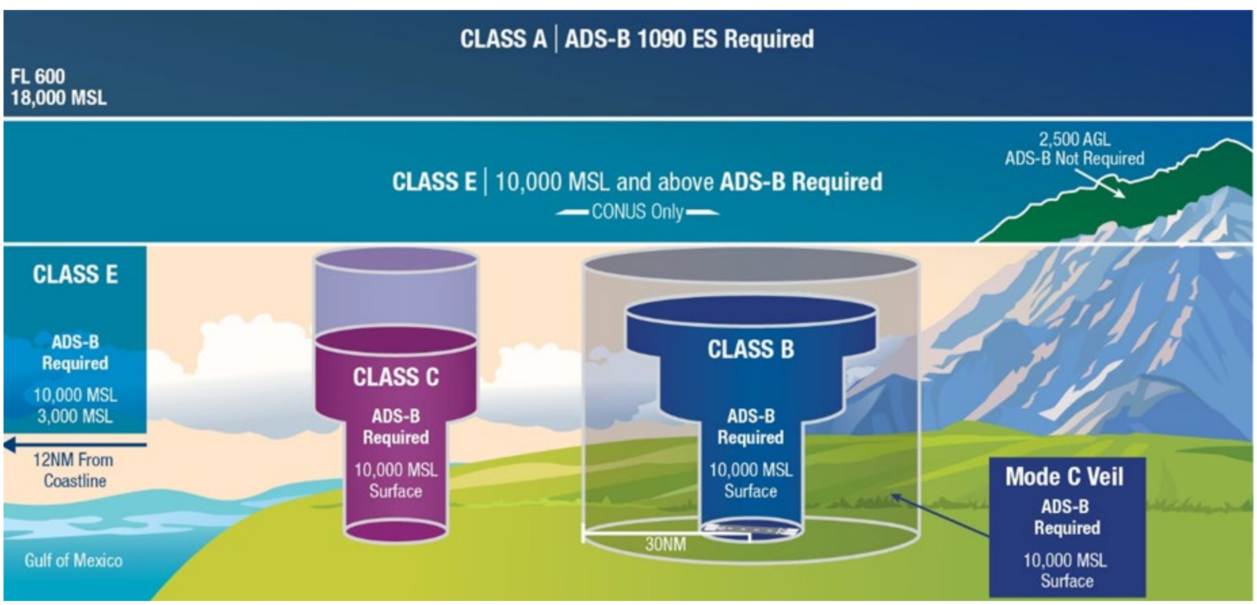


Figure 35: ADS-B required airspace. Source: FAA
https://www.faa.gov/air_traffic/technology/equipadsb/research/airspace

The ADS-B Out requirements do not apply in the airspace defined above (Figure 35) for any aircraft not originally certificated with an electrical system or that has not subsequently been certified with such a system installed, including balloons and gliders. Such aircraft may also operate within the Mode C veil as long as they remain outside the lateral boundaries of Class B or C airspace.

Aircraft complying with this rule are considered cooperative. It is important to note the airspace classes that require ADS-B Out are controlled airspace. There is not currently a rule requiring any aircraft to cooperatively transmit ADS-B information in Class G (uncontrolled) airspace where the majority of UAS operate. Figure 36 provides an overview of the low altitude ADS-B required airspace in Virginia.

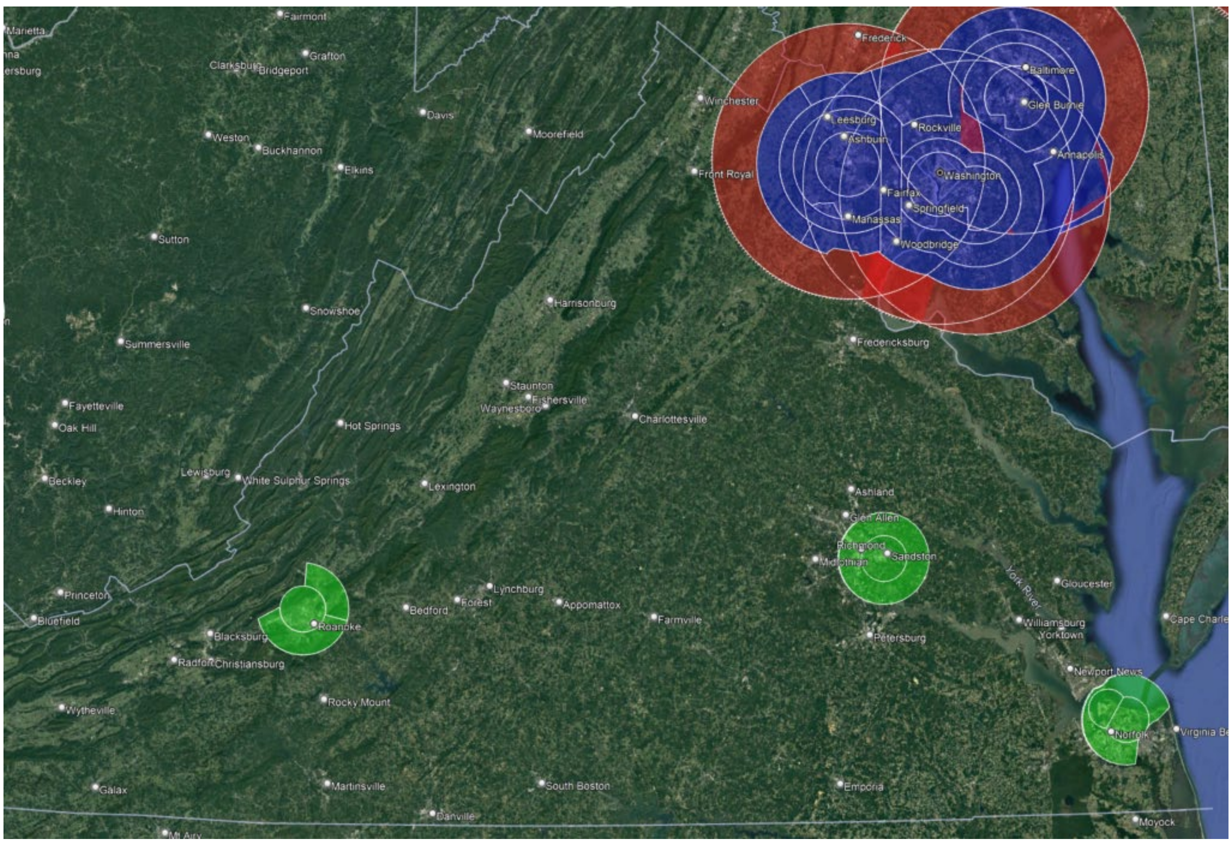


Figure 36:Description of ADS-B required airspace in Virginia. Class B airspace (blue) surrounding Washington, as well as the Mode C veil (red), which is within 30 NM of Class B airspace, and Class C airspace (green) surrounding Roanoke, Richmond, and Norfolk.

9.1.1.2 Different Types of Airspace Surveillance Sensors

Ground-based airspace surveillance sensors utilize a variety of detection methods therefore capabilities of each sensor vary in terms of range, performance, and applicability depending on each environment and use case. Although sensors may support a variety of operations simultaneously and provide wide area coverage for multiple users, ground-based sensors do pose some unique challenges in terms of range, field of view, latency, reliance on communications links, and other issues specific to the sensor and operation. As discussed in Section 9.1.1.1, detection of both cooperative and non-cooperative aircraft may be required.

Cooperative Intruder Sensors

Cooperative intruder sensors are typically ABD-B receivers, which receive the information that is being actively transmitted from cooperative aircraft. These receivers are readily available, relatively low cost, and provide excellent detection of ADS-B equipped aircraft. It is important to note that in addition to supporting UAS use cases, ADS-B receivers may also be used for situational awareness and safety across other AAM and traditional aviation areas. An example of an all-in-one ground-based ADS-B receiver, with GPS, antenna, IP67 weatherproof enclosure, and power and data provided by a single Power-Over-Ethernet network cable is shown in Figure 37, with a maximum range of 200 miles, small footprint (26in H x 7in W x 1.5in D).

In addition to specific sensors, several companies offer cooperative aircraft tracking data as a service, which may be obtained on a subscription service and distributed across a network or integrated with other services such as VAFIX. Examples of cooperative aircraft tracking data include FlightAware, whose Firehose Data Feed provides airborne position data from their terrestrial network of ADS-B receivers (Figure 38).

Beginning September 16, 2023, all UAS registered with the FAA will be required to utilize Remote ID (RID) modules. RID modules are similar in concept to ADS-B technology, in that cooperative UAS will broadcast relevant information, such as position, to other nearby relevant parties. RID modules differ from ADS-B in that their conception and design is specifically intended for a cooperative UAS environment, with emphasis being placed on minimizing cost, mass, and form factor, to make them viable for small platforms. Implementation of a cooperative environment based on RID may take different forms as the landscape matures. For example, UAS may simply broadcast information in traditional fashion, or an internet-based networked solution might be employed, with USS or other providers forwarding and distributing the broadcasted information. An example of a current RID module option is shown in Figure 39, while Figure 40 shows examples of fixed site RID receivers.

Figure 37: Example of a ground-based ADS-B receiver. Source: uAvionix
https://uavionix.com/products/pingstation-3/

Figure 38: Example of terrestrial ADS-B data service provider coverage. Source: Flight Aware [*https://flightaware.com/adsb/coverage#data-coverage*](https://flightaware.com/adsb/coverage#data-coverage)

Figure 39: Example of RID module. Source: uAvionix https://uavionix.com/products/pingrid/

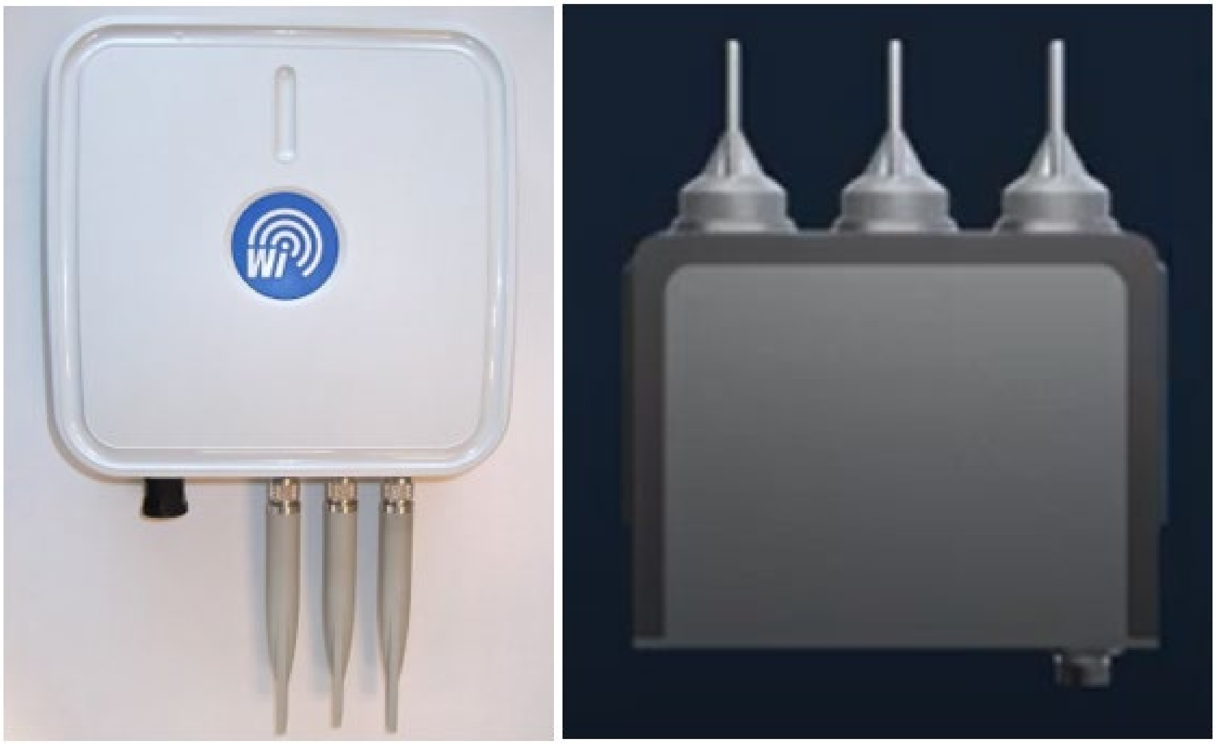


Figure 40: Examples of a Remote ID Readers. Source- DroneScout (left) https://dronescout.co/dronescout-remote-id-receiver/ and AirWarden (right) https://www.aerodefense.tech/airwarden-remote-id-receiver#deployment-options

Non-Cooperative Intruder Sensors

Technology infrastructure selection for addressing airborne risk mitigation, specifically detection of non-cooperative aircraft, may rely on active or passive sensors, including radar, optical, and acoustic options. Each type of sensor will have its own set of benefits and challenges dependent on such factors as environment, geography, range, and use case specific risks.

Radar (Short, mid, and long range)

Ground based radars are technically mature and may offer greater coverage for multiple users over other types of sensors. The challenges associated with a ground-based system include matching required range and capabilities with end user requirements while also determining the best location for emplacement. A selection of examples of various radar platforms are shown below, ranging from short range to long range, and incorporating various design and performance features such as 360-degree coverage and 3D capabilities.

Echodyne Echoguard – 1.5mi

The Echodyne Echoguard (Figure 41) is a radar specifically designed for UAS detection and tracking in various environments, capable of providing situational awareness of an airspace. The Echoguard lists a range of 1.5mi for detecting an aircraft the size of a Cessna, and 1.4km for a DJI Matrice 600.

Figure 41:A two-panel Echodyne Echoguard array with connection hub shown as a ground-based sensor mounted on a tripod (left), as well as a four-panel array mounted on a mast for increased viewshed (right). Source: Virginia Tech Mid-Atlantic Aviation Partnership. https://maap.ictas.vt.edu/

Echodyne Echoshield – 6mi.

EchoShield (Figure 42) is a software-defined, medium-range, pulse-Doppler, cognitive 4D radar for radionavigation and radiolocation applications. is designed for rapid optimization to user, location, and requirements. Software configuration from a menu of Mission Sets utilizes tailored waveforms and agile beam schedules to rapidly deliver various performance parameters.

Figure 42: Echodyne Echoshield 4D radar. Source: Echodyne -https://www.echodyne.com/radar-solutions/echoshield/

Sparrowhawk – Canadian UAV 9 mi

The Sparrowhawk (Figure 43) is a ground-based radar solution developed by Canadian UAV that lists an operational range of up to 9.2mi. The radar has a 360-degree FOV and position accuracy of 100m, and radiator length of 6ft.

Figure 43: Example of the Sparrowhawk. Source: https://www.canadianuavs.ca/products/sparrowhawk-radar

TERMA – ND 15mi

The Scanter 5000 Series (Figure 44) is a series of radars developed by TERMA. These radars list a range of around 15 mi. and operate in a variety of use cases. Notably, these radars are currently used in the Vantis network of the Northern Plains UAS Test Site in North Dakota.

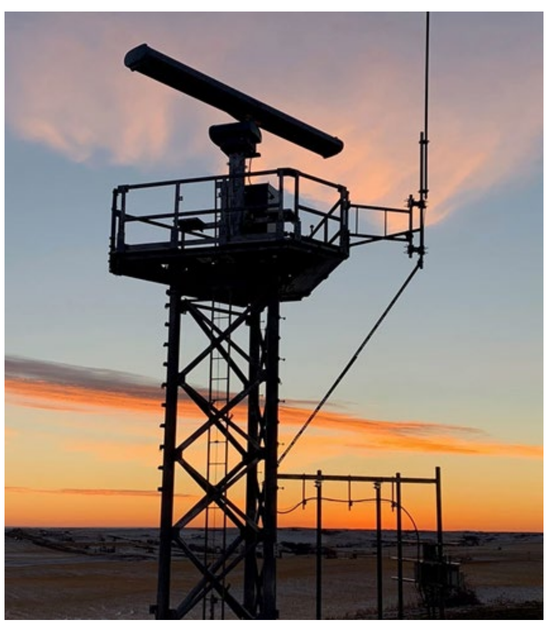


Figure 44: Example of Scanter 5202. Source: https://www.terma.com/news-events/news/news-archive/protecting-north-dakota-skies-for-safe-unmanned-aircraft-system-operations/

LSTAR – NY 24mi

The LSTAR is a series of radars produced by SRC (Figure 45), with a listed range of 24mi. This radar is listed as supporting a variety of use cases, but has an emphasized use case as being able to reliably detect and track a large variety of UAS platforms. This radar series is employed at the New York UAS Test Site.

Figure 45: Example of LSTAR radar. Source: https://www.srcinc.com/products/radar/lstar-air-surveillance-radar.html

Optical

IRIS Casia G – NV 1.2mi.

The IRIS Casia G (Figure 46) is an optical solution designed to identify and track UAS in the nearby airspace. The Casia G leverages computer vision technology and machine-learning algorithms to detect automatically visually detect aircraft. The Casia series offers onboard and ground-based solutions, and lists a range of 1.2mi for each system.

Figure 46: Example of Iris Automation 360-degree optical sensor. Source: Iris Automation https://www.irisonboard.com/

Acoustic

SARA Tasa 2.5 – 4mi.

The SARA Tasa (Figure 47) is an acoustic DAA system leveraging the unique acoustic characteristics of UAS. Some UAS can be heard at distances of multiple miles, with their propellers generating distinct frequencies compared to other noises in the environment. The SARA Tasa system lists a range of up to 4 miles with a 360 degree FOV.

Figure 47:SARA TASA acoustic node deployed on a telescoping mast. Source: Virginia Tech Mid-Atlantic Aviation Partnership. https://maap.ictas.vt.edu/

Table 7: Summary of airspace surveillance technology options.

	Sensor Type	Limitations	Coverage	Cost
ADS-B	Cooperative - Passive	Relies on cooperation Not UAS-centric	360 degrees 200mi.	$
RID	Cooperative – Passive	Relies on cooperation New and changing tech	360 degrees 1.86mi.	$
Optical	Non-Cooperative -Passive	Limited range	360 degrees 1.25mi.	$$
Acoustic	Non-Cooperative -Passive	Limited Range Relatively unproven	360 degrees 2.5 - 4mi.	$$$
Radar	Non-Cooperative - Active	Costly Active Transmission	Up to 360 degrees 1.5 - 25mi. +	$$-$$$$

9.1.2 UTM Model

UTM is envisioned to serve as an enabler for UAS integration into low altitude airspace. UTM allows for private industry, with FAA oversite, to provide services to multiple UAS operators for the coordination, execution, and management of operations in areas where inherently governmental services provided to traditional aviation are not available to UAS operations.

The FAA does not currently prescribe UTM implementation methods, however a framework was provided that demonstrates a viable path for attaining regulatory approval (Figure 48). By following this approval pathway, near-term solutions may be implemented that enable scaled use of services while also setting precedent for end-user entry to BVLOS flight within an approved SDSP service area (Figure 49).

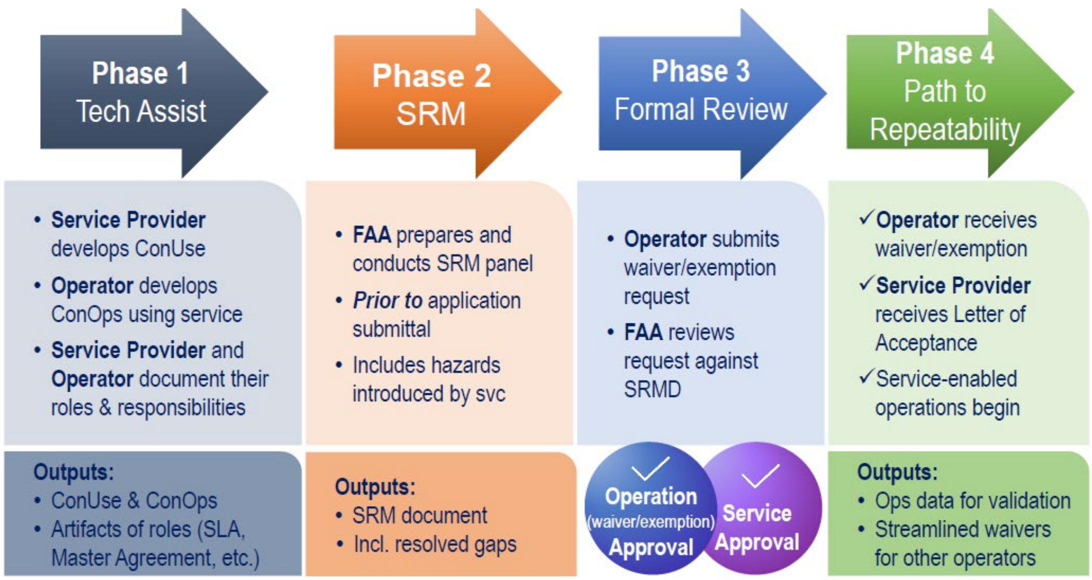


Figure 48: FAA Near-Term approval process for UTM enables operations within an FAA approved surveillance volume. Source: FAA BEYOND Plenary Meeting May 17, 2022.

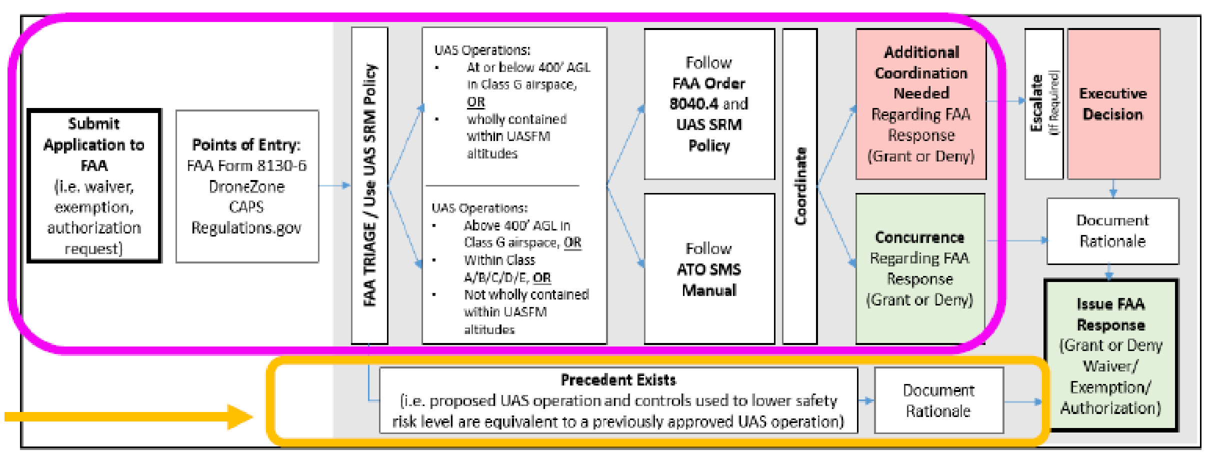


Figure 49: UTM Model Champion operator (magenta)and Follow-On use (gold) case approval process. Source: FAA BEYOND Plenary Meeting, May 17, 2022

Establishing MVI within a UTM Model

Providers of the MVI will be required to gain regulatory approval for the services being offered. Once full system validation has been verified, a ConUse document may be compiled that explains to the FAA the full extent of the services being offered, including relevant unmitigated risks, test data, and post-mitigation residual risks. This may also include the Service Level Agreement (SLA) that explains the services offered, restrictions, limitations, and requirements to end users.

Use of MVI within a UTM Model

End users will be required to gain regulatory approval for the use of the services being offered as a means of risk mitigation. End users who's planned operations include activities outside of the provisions of 14 CFR Part 107 will need to apply for waiver or exemption from the FAA. MVI is intended to help end users answer questions pertaining to risk mitigation strategies used in a waiver application by providing technology infrastructure and oversight via pre-established rules and procedures. End users may reference the MVIU Service Approval and corresponding SLA for some portions of the waiver application, thus removing the burden of full testing and demonstrations identified in Phase 2 of the MAAP Safety Case Development Process.

9.1.3 Communications

The integrity of the command and control (C2) link between operator and UA, and the encryption and security methods in place to protect the flow of data are essential in enabling advanced AAM operations. Traditionally, UA have utilized unlicensed spectrum for C2, which does not protect against interference from outside sources. The FAA has determined[26] that while conducting operations in controlled airspace or BVLOS, a licensed band C2 may be required in order to mitigate against interference and tampering. Licensed band refers to frequencies that have been allocated to certain users by the FCC that guarantee against interference, such as television, radio, and cellular. In the creation of the Part 107 regulations, the FAA specifically discussed the frequency spectrums (RF) basics and what is expected from every UAS. Commonly used UAS C2 frequencies such as 2.4 GHz and 5.8 GHz are generally limited to line-of-sight operations in order to mitigate against obstacles causing interference issues. The 2.4 and 5.8 GHz frequencies fall within the FCC's ISM band, which is a portion of the radio spectrum reserved internationally for industrial, scientific and medical purposes, excluding applications in telecommunications. In using this band, all users must accept any interference they might encounter, which may pose a reliability issue when conducting operations in controlled airspace or beyond line of sight. For this reason, the FAA prescribes licensed spectrum C2 for these type operations, which requires allocation and approval from the FCC. Additional options such as cellular or satellite based C2 may be used, however industry standards and minimum performance requirements have not yet been established. Several companies, including uAvionix,(Figure 50) have gained regulatory approval for use of licensed band C2 solutions for BVLOS operations, particularly in North Dakota as integrated into their Vantis network.

[26] https://www.faa.gov/documentLibrary/media/Advisory_Circular/Editorial_Update_AC_107-2A.pdf

Figure 50: Example of an aviation-protected C-Band (5030-5091 MHz) bi-directional, Multiple Input & Single Output (MISO) dual Control and Non-Payload Communications (CNPC) radio system antenna. Source – uAvionix https://uavionix.com/products/ground-radio-systems/#specs

9.1.4 Weather Sensors

Aviation weather sensors may be scaled for intended use by seperation into individual components or packaged as a complete system. Options may include basic information such as wind speed and direction, and temperature and dew point for smaller scale operations, while more advanced operations covering a larger area may add cloud height or lightning sensors. Examples of individual weather sensor components are shown below in Figure 51, while Figure 52 shows an example of an all-in-one micro weather sensor that combines multiplr weather sensing components into one unit.

Additionally, in keeping with the UTM architecture described in Figure 5 and Figure 26, a weather SDSP may be integrated to interperate and display use-case specific weather products based on input from the weather sensor network combined with outside, existing weather sensors to give users both real-time and predictive weather information (Figure 53).

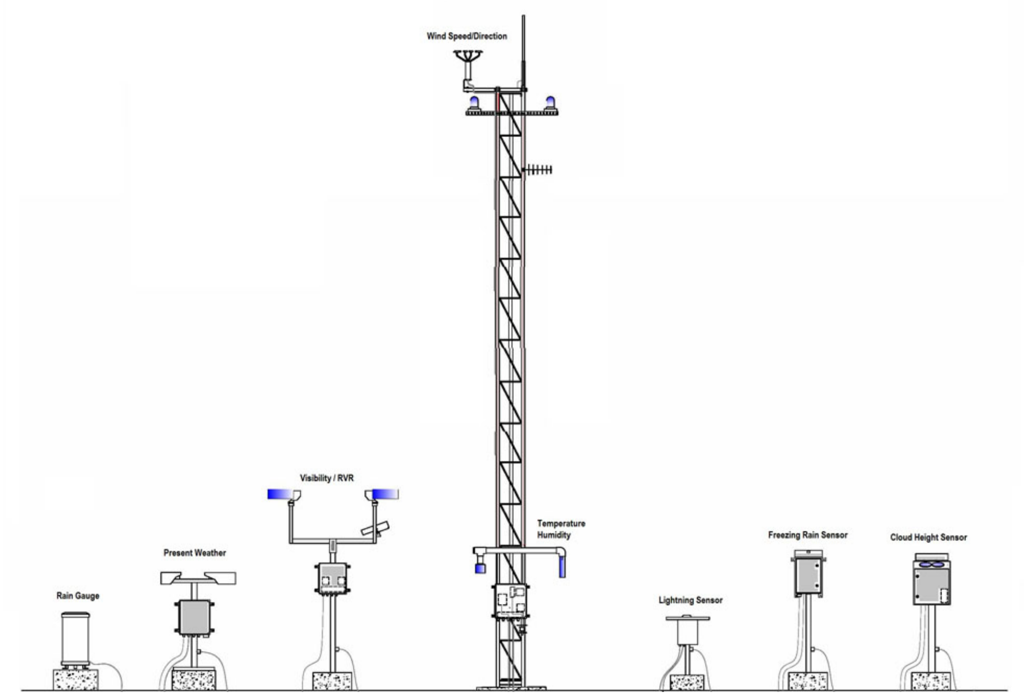


Figure 51: Example of various weather sensing components (from left to right) Rain gauge, present weather, visibility, wind speed & direction, temperature & humidity, lightening, freezing rain, and cloud height.. Source – AllWeather Inc. https://www.allweatherinc.com/international-automated-weather-observation-system/#tabs=754

Figure 52: Example of a micro weather sensing unit that combines multiple weather sensors into a single package. Source: Intellisense Systems https://www.intellisenseinc.com/products/weather-stations/mws-c400/

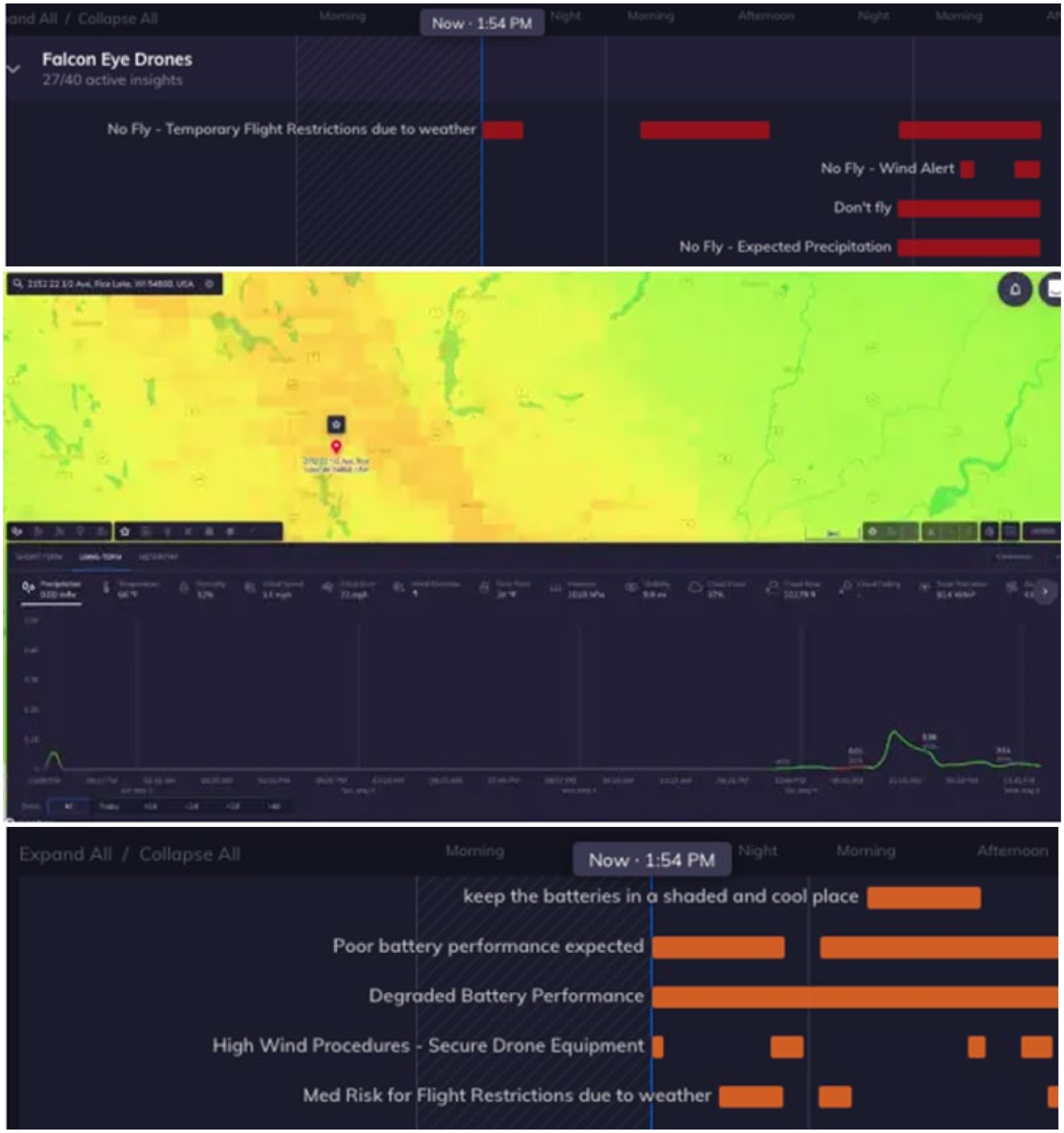


Figure 53:Examples of use case and mission-specific weather information, such as impact of forecast on operational schedule (top), micro-level real-time and forecast products (center), and recommendations on how to mitigate weather risks (bottom). Source: Tomorrow.io https://www.tomorrow.io/solutions/drones/

9.2 Non-Technology-Based Risk Mitigation Strategies

There are certain circumstances where the FAA may allow for advanced AAM operations such as public safety missions (Fire, Police, Emergency Management), linear infrastructure inspections (power lines, pipeline for example) and other commercial operations (construction and real estate for example) without the use of airspace surveillance technologies. In these cases, specific criteria must be met in order to qualify for consideration.

9.2.1.1 Shielding as an Air Risk Mitigation

The FAA conducted a Safety Risk Management (SRM) panel using shielding (commonly called masking and/or shielding where the UAS is flown within 50' above or laterally from an obstruction) and the use of Automatic Dependent Surveillance-Broadcast (ADS_B) 'IN' as primary mitigation for the UAS to detect and avoid other aircraft (14 CFR Part 107.31).

Based on this SRM, applicants can apply for a Beyond Visual Line of Sight Obstruction Shielding (BVLOS-OS) waiver if the following safety mitigations are met:

- The flight operation must remain within 50 feet above and laterally from a man-made or natural obstruction
- The flight operation is limited to a maximum altitude (hard ceiling) of 400 feet above ground level (AGL)
- Must be a civil operator operating under 14 CFR Part 107
- All 14 CFR Part 89 and 107 regulations apply to the operation
- All 14 CFR Part 91 regulations apply to crewed aircraft
- Flight operations are limited to daytime Visual Meteorological Conditions (VMC), in accordance with 14 CFR Part 107
- Notice to Air Mission (NOTAM) to be filed for applicable operations
- The flight operation must have and utilize ADS-B IN to assist in alerting the operations of other aircraft in the area
- While a visual observer (VO) is NOT required for the BVLOS-OS waiver, a VO has the potential to enhance the safety of the operation
- The flight operations must be in Class G airspace

Various examples of shielding operations are shown in Figure 54 - obstruction shielding, Figure 55 - non-critical infrastructure shielding, and Figure 56 – critical infrastructure shielding.

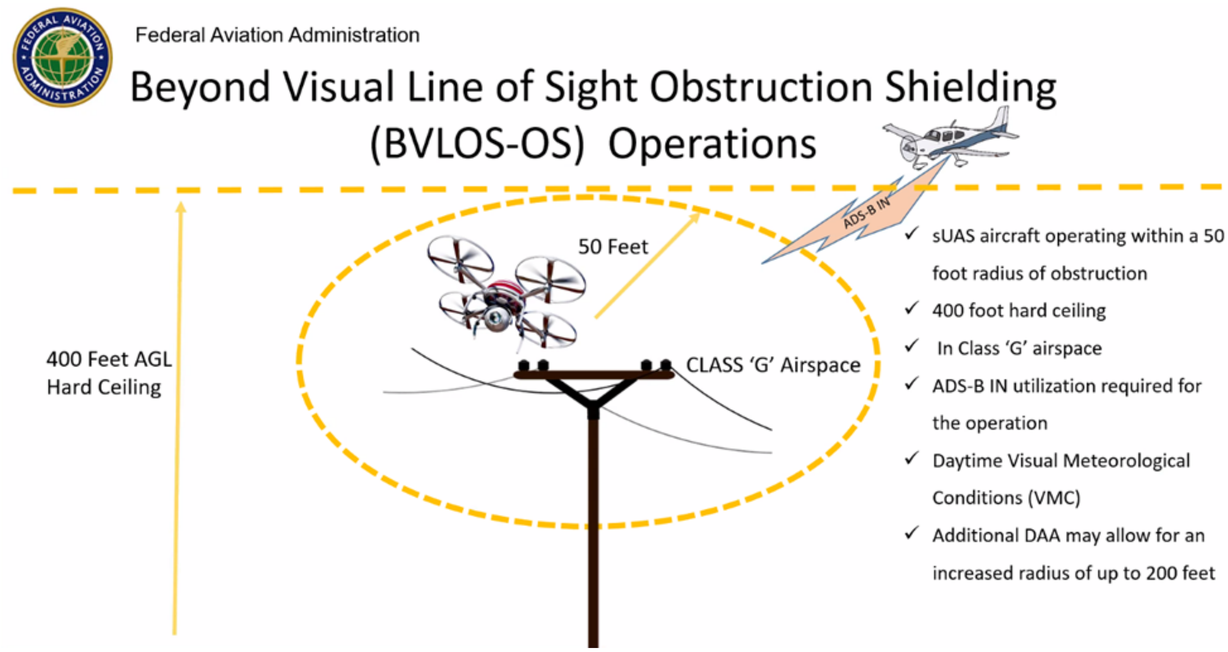


Figure 54: BVLOS-Obstruction Shielding Operations. Source: FAA Beyond Roundtable May 2023

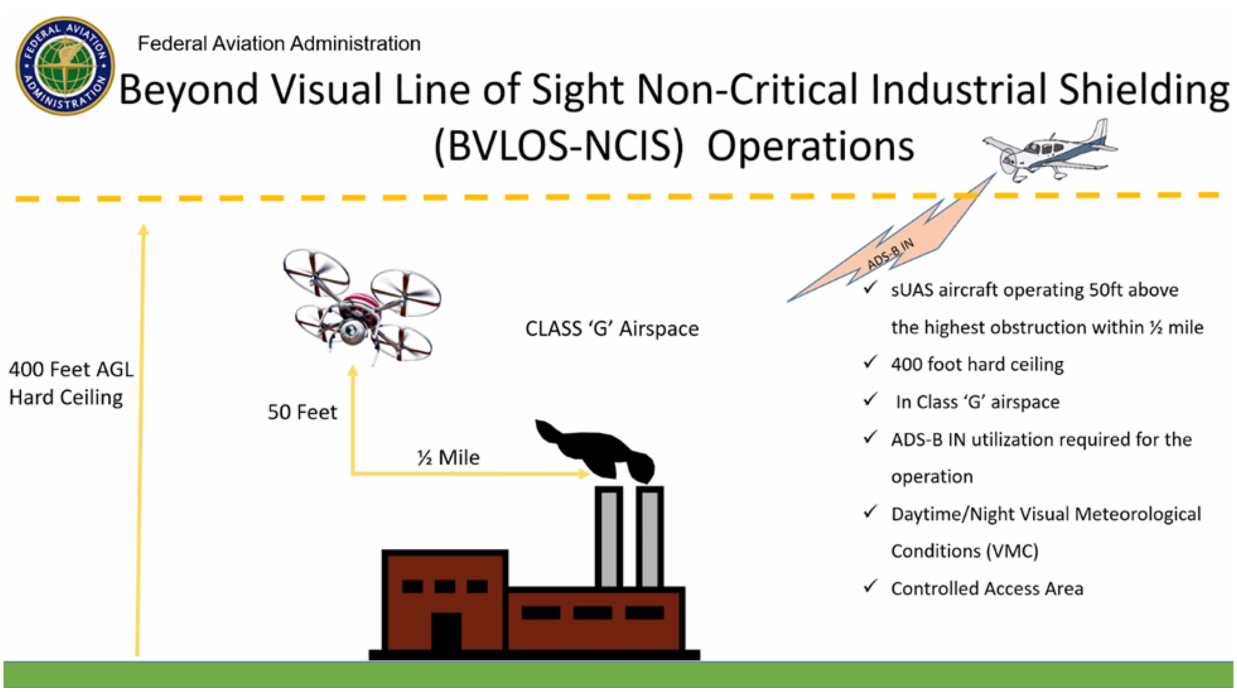


Figure 55: BVLOS Non-Critical Industrial Shielding Operations. Source: FAA Beyond Roundtable May 2023.

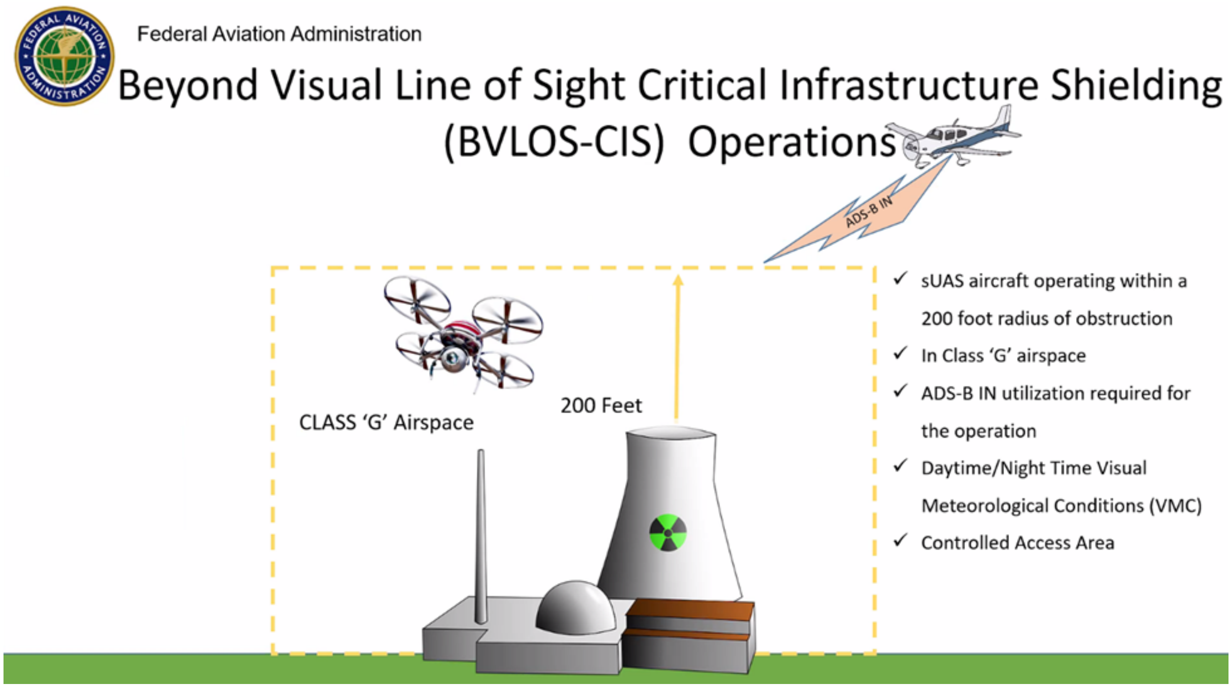


Figure 56: BVLOS-Critical Infrastructure Shielding Operations. Source: FAA Beyond Roundtable May 2023.

9.3 Ground Risk Mitigation Solutions

As discussed in Section 8.1.2, Ground Risk refers to the potential for the UA to cause harm to non-participants or property on the ground underlying the intended operational area. The technology used to help mitigate any identified ground risks may include aeronautical charts and obstruction databases for avoidance of ground-based obstructions such as towers, powerlines, and smokestacks. Flight planning software may incorporate these obstruction databases to assist the pilot in avoiding potential collisions with obstructions.

UAS selection may play a significant role in ground risk mitigation through various mechanisms to ensure safety such as airworthiness certifications, operating procedures, and robust maintenance plans. The FAA manages aircraft ground risk via injury severity testing and Type Certification processes that provides them data confirming the aircraft has met certain safety requirements for design, manufacture, and operation. Conformance with an FAA approved Means of Compliance or Type Certification may be required for certain operators and flight profiles.

9.3.1 Software Solutions

The FAA provides obstruction data map (Figure 57) and a downloadable database that is updated every 56 days. This database contains information on man-made objects that affect aviation charting products, including objects of any height within 5NM of a charted airport, and objects above 200'AGL outside of 5NM from a charted airport.

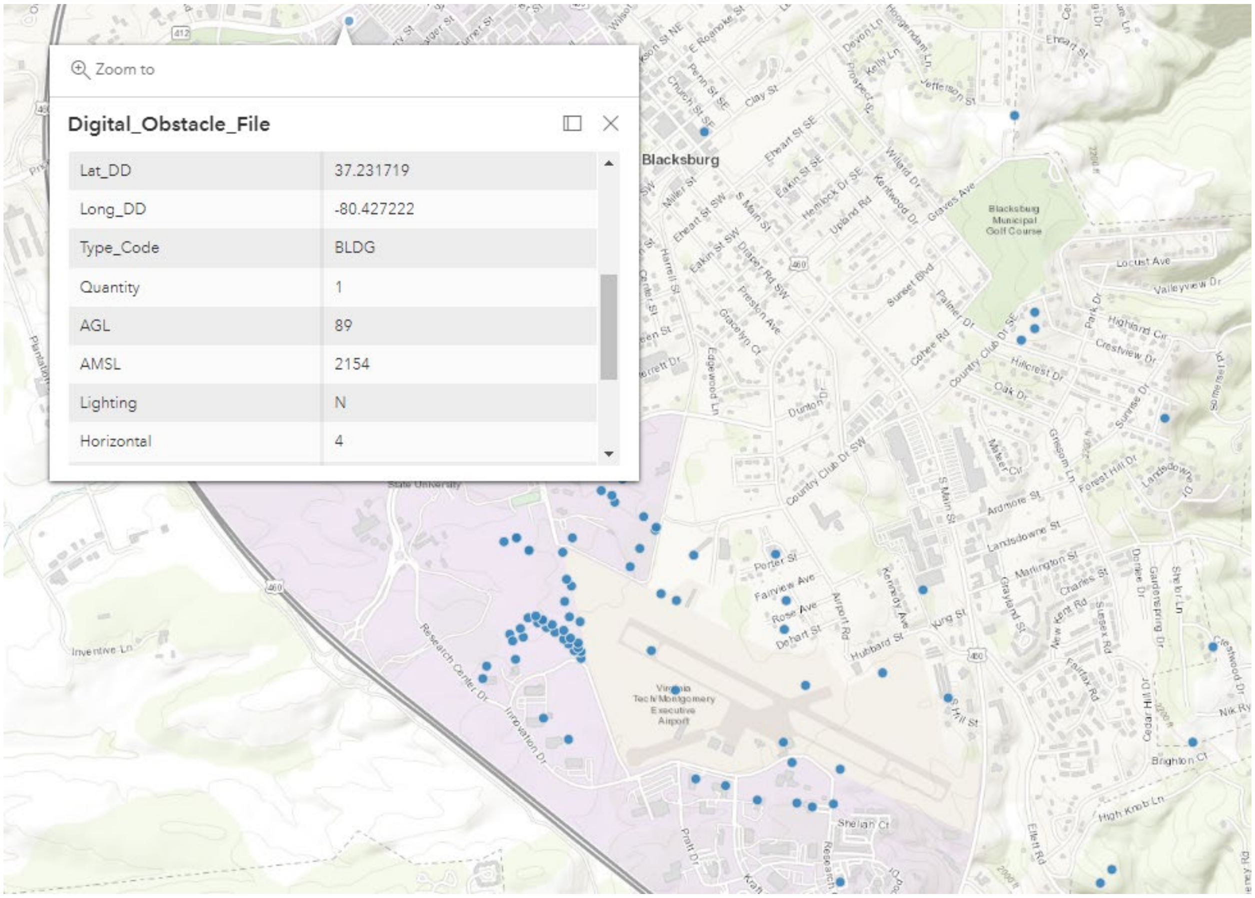


Figure 57: Example of the FAA's Digital Obstruction File database depicting a building at 89'AGL northwest of the Blacksburg, Va. airport.

Since UAS frequently operate below 200'AGL outside of 5NM of an airport environment and/or over uneven terrain, additional data may be required to ensure Beyond Visual Line of Sight flights are conducted safely in regard to terrain and obstruction avoidance. UAS mission planning software (Figure 58) may include built-in features that combine multiple data sources beyond the FAA obstruction database, such as terrain data from the Shuttle Radar Topography Mission (SRTM) from NASA and the 3D Elevation Program (3DEP) from the US Geological Survey. Certain software products will also allow users to import custom obstruction and terrain data from other sources such as LiDAR scans to create location and mission specific reference data.

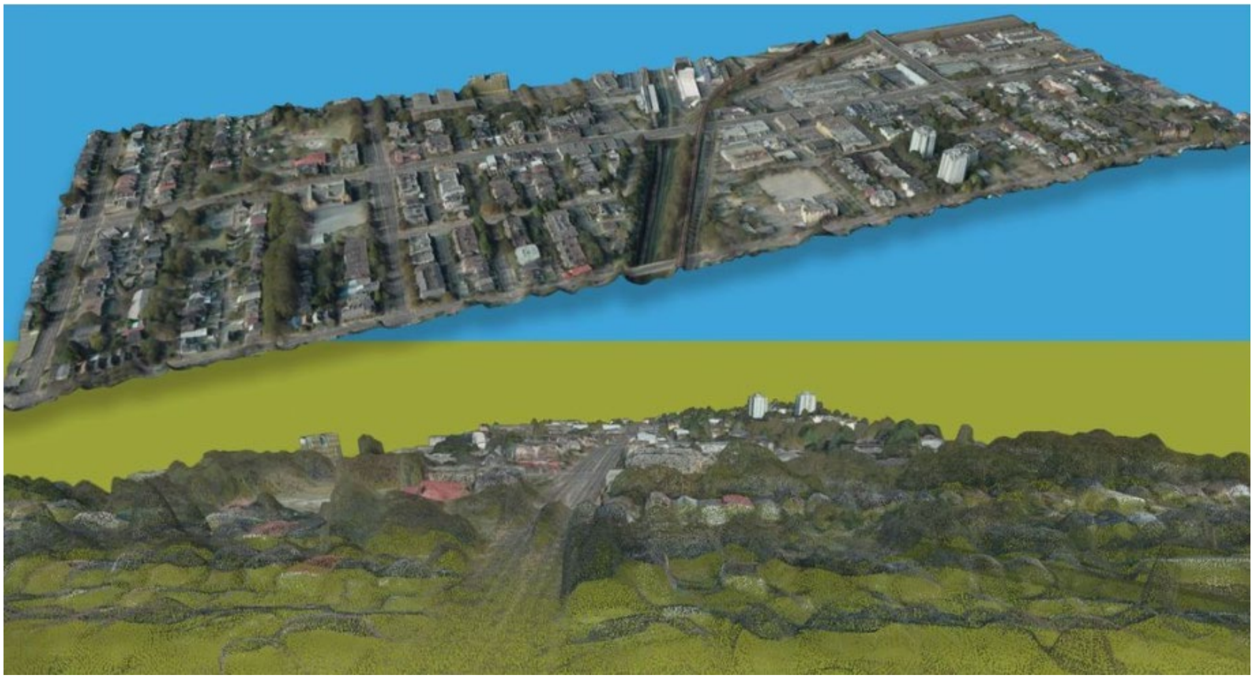


Figure 58:Example of custom terrain and obstruction map products available through geospatial software integrated with mission planning and control software. Source: Kongsberg Geospatial. https://www.kongsberggeospatial.com/products/terralens

MAAP and the Virginia Tech Airworthiness Center (VTAC) have been researching and developing tools for analyzing ground risk since 2018. VTAC developed the Quantitative Approach and Departure Risk Assessment (QUADRA) tool for Naval Air Systems Command (NAVAIR) to gain a better understanding of the risk to third parties on the ground should a crash of a crewed or Uncrewed Aerial Vehicle (UAV) occur. While the tool focuses on the approach and departure phase of flight it can be used for analyzing ground risk for all flight phases[27,28].

To calculate ground risk QUADRA utilizes the LandScan population database, which was developed by Oak Ridge National Laboratory. LandScan is one of the best population databases and generates its population maps through combining government censuses, satellite imagery, and National Databases such as National Center of Education Statistics for School time populations. Through the combination of all these data sources, LandScan creates a map of population that goes beyond typical census data alone. For the tests run in the Contiguous United States, LandScan USA is used due to its higher resolution, as well as having temporal data that is split up into daytime and nighttime population distributions. For all other tests, LandScan Global is used as it has complete population data for the entire Earth.

[27] B. S. Gobin, "Quantitative Approach and Departure Risk Assessment Unmanned Aerial Systems," Virginia Tech MS Thesis, Blacksburg, 2020.

[28] B. Gobin, R. Briggs, R. Canfield, D. Adie, and T. Jones, " Quantitative Approach and Departure Risk Assessment (QUADRA) Theoretical Manual", 2022.

The user of QUADRA inputs the intended flight path, aircraft parameters and failure rate information for the aircraft. QUADRA then calculates a probable crash area for each point in the flight path based on the aircraft dynamics and failure modes (Figure 59). Examples of failure modes include: gliding, loss of flight control and flight termination system activation. The tool then uses the population database to assess the ground risk within the probable crash area.

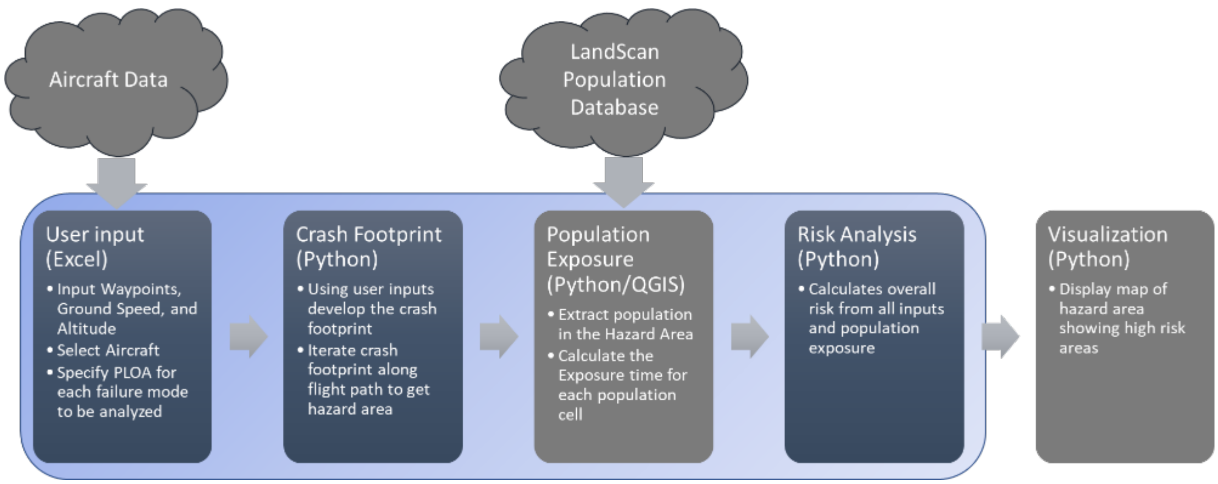


Figure 59: QUADRA software outline

9.3.2 UAS Operations Over People

Title 14 of the Code of Federal Regulations Part 107 was amended to provide a pathway for permitting the routine operation of small UAS over people and/or moving vehicles under certain conditions. The final rule establishes four categories of small unmanned aircraft for routine operations over people and/or moving vehicles.

- **Category 1** UA are those weighing less than 0.55 lbs. and may provide very limited use to governmental or commercial use cases.
- **Category 2 and 3** UA are determined through injury risk assessment testing in accordance with an FAA approved Means of Compliance[29].
- **Category 4** UA are those which have received a Type Certification from the FAA[30].

Each category of UA is associated with specific operating rules and restrictions based on the level of ground risk it represents (Table 8).

[29] https://uasdoc.faa.gov/listMOC
[30] https://www.faa.gov/uas/advanced_operations/certification

Table 8: Operations Over People and Moving Vehicles Categories, Requirement, and Restrictions

Category	Requirements	Flight Over Non-Participating People?	Non-Sustained Flight Over Open-Air Assemblies?	Sustained Flight Over Open-Air Assemblies	Flight Over Moving Vehicles
1	<0.55lbs. No exposed rotating parts	Yes	Yes	Yes. w/ RID	Non-Sustained only
2	Category 2 MOC/DOC	Yes	Yes	Yes. w/ RID	Non-Sustained only
3	Category 3 MOC/DOC	Non-Sustained Only	No	No	Non-Sustained only
4	Airworthiness Certification	Yes	Yes	Yes. w/ RID	Non-Sustained only

Demonstrations of compliance with the requirements for Categories 2 and 3 may be performed via an FAA approved Means of Compliance, which provides the FAA with the required test and compliance data necessary for classification. Figure 60 shows Virginia Tech's FAA approved Means of Compliance process.

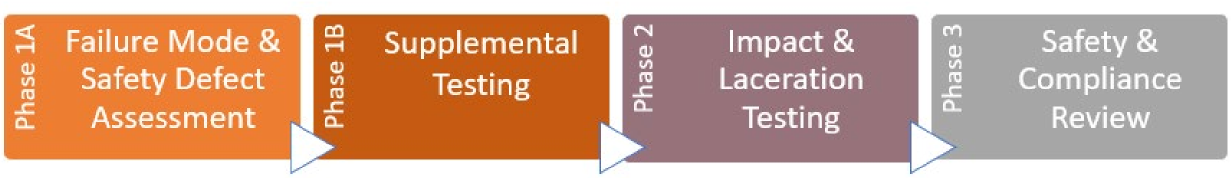


Figure 60: Virginia Tech MAAP FAA accepted Means of Compliance process

9.4 Example of Technology Selection for Example Use Cases

The technology selection process is performed in response to the unmitigated risks discovered in the risk assessment process. This step is meant to utilize technology as a means of mitigating identified risks to an acceptable level of safety for the intended operations, as well as satisfy mission-specific operational requirements. This section demonstrates how the example Areas and Use Cases may be combined with the appropriate technologies to enable operations.

9.4.1 Example Technology Selection for Use Case 1 - DFR

Based on the unmitigated risks associated with DFR operations in an Urban environment, along with the Use Case specific operational requirements, the following technologies may be used:

Table 9: Example DFR Use Case Technology Selection

Identified Risk or Operational Requirement	MVI Technology
Cooperative crewed traffic awareness	ADS-B in receiver
UAS traffic awareness	RID reader
Real-time, location-specific weather monitoring and reporting	Micro Weather sensor
Non-cooperative crewed traffic awareness	Short-Range Fixed-Site Optical Sensor
Non-cooperative crewed traffic awareness	Short-Range Fixed-Site Radar Sensor
Situational awareness and operational oversite and management	Sensor track fusion, Airspace alerting, and Fleet management software solution

The technology selection for the DFR Use Case may include airspace deconfliction tools such as cooperative and noncooperative airspace surveillance sensors for traditional crewed aircraft to enable localized BVLOS operations. Other situational tools such as RID readers may be used for deconfliction with non-participating UAS, as well as weather detection and reporting sensors for location specific micro weather. Software solutions may also be utilized to plan and manage operations, as well as fuse sensor tracks and provide situational awareness displays and alerting to system users.

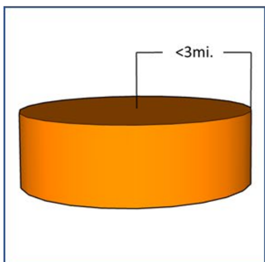
Based on the specific requirements of this example use case, the short-range fixed-site MVI model may be the most effective. This model is intended to support localized operations and may be customized based on use case needs, which allows for a scalable solution. For expanded areas, multiple sensors may be networked to form a larger surveillance and operations area. Placement options include on top of Police/Fire stations or other municipal buildings such as water towers and communications towers.

Area

Densely populated urban areas that receive a high volume of First Responder calls

Use Case

Drone as a First Responder



MVI Strategy

Short-Range Fixed-Site

9.4.2 Example Technology Selection for Use Case 2 – Medical Delivery

Based on the unmitigated risks associated with Medical Delivery operations in a Rural environment, along with the Use Case specific operational requirements, the following technologies may be used:

Table 10: Example Medical Delivery Use Case Technology Selection

Identified Risk or Operational Requirement	MVI Technology
Cooperative crewed traffic awareness	ADS-B in receiver
UAS traffic awareness	RID reader
Real-time, location-specific weather monitoring	Micro Weather sensor
Non-cooperative crewed traffic awareness	Medium-Range Fixed-Site Sensor
Situational awareness & operational oversite	Sensor track fusion, Airspace alerting, and Fleet management software solution
Secure C2 Communications for BVLOS flight	Licensed band C2

The technology selection for the Medical Delivery Use Case may also include sensors similar to other Use Cases such as airspace surveillance, RID readers and weather detection and reporting sensors, although on a slightly larger scale due to the longer distances involved. This may also require longer-range communications systems, specifically licensed band C2, such as Cellular or Satellite-based solutions. Similar software platforms may also be utilized to plan and manage operations, as well as fuse sensor tracks and provide situational awareness displays and alerting to system users.

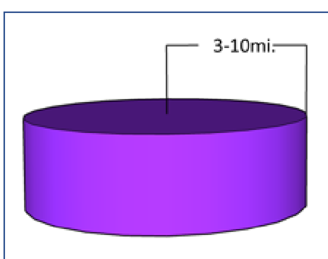
In order to meet the safety and operational requirements of this use case, a Medium-Range Fixed-Site MVI model may be used, which is intended to support localized routine operations for a specific use case. Placement options include on roof of the Fire Station or Hospital, or other municipal buildings including water towers and communications towers.

Area

Rural communities that are traditionally difficult to serve due to geographical challenges

Use Case

Medical Delivery (emergency and non-emergency)



MVI Strategy

Medium-Range Fixed-Site

9.4.3 Example Technology Selection for Use Case 3 – On-Demand Emergency Response

Based on the unmitigated risks associated with On-Demand Emergency Response operations at various locations across the Commonwealth, along with Use Case specific operational requirements, the following technologies may be used:

Table 11:Example On-Demand Emergency Response Use Case Technology Selection

Identified Risk or Operational Requirement	Technology
Cooperative crewed traffic awareness	ADS-B in receiver
UAS traffic awareness	RID reader
Real-time, location-specific weather monitoring and reporting	Micro Weather sensor
Means of transporting MVI and associated equipment and management of operations	Mobile Operations Command Center
Non-cooperative crewed traffic awareness	Medium-Range Mobile Radar Sensor
Data collection mechanism paired with MVI	ISR capable UAS platform
Situational awareness and operational oversite and management	Sensor track fusion and Airspace Alerting Software Solution
Secure C2 Communications for BVLOS flight	Licensed band C2
Wireless network data access for connectivity in austere environments	Cellular and Satellite based voice and data communications system

The technology selection for the On-Demand Emergency Response Use Case may also include airspace surveillance, RID readers and weather detection and reporting sensors similar in ability to the Medical Delivery Use Case. Due to the nature of the operations, a mobile platform in the form of a trailer or dedicated vehicle will be needed to house and transport the equipment. Specific UAS recommendations would be at the discretion of the individual users for other Use Cases since they will most likely be building fleets of aircraft in support of their Use Cases. For this particular Use Case, it may be recommended to pair a specific UAS with each mobile command center since they will not be part of a large fleet. Specifically, a Vertical Takeoff and Landing (VTOL) Fixed-wing hybrid UA is recommended that allows for more flexibility in choosing takeoff and landing locations, while also enabling longer flight endurance over multi-rotor UA. This type of UA may also be capable of hot-swappable sensor packages to correspond to various mission sets, meaning they can be quickly changed by field personnel without specialized tools or equipment.

This Use Case may also require licensed band C2 solutions and software platforms to plan and manage operations, fuse sensor tracks, and provide situational awareness displays and alerting to system users. An additional wireless voice and data communications setup may be required to share UA sensor feeds and other information across State agencies in real-time.

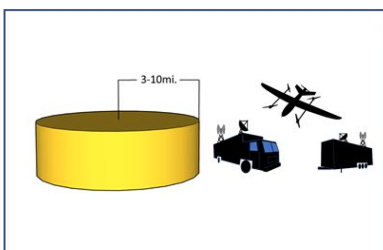
In order to support the intended operations, a Medium-Range Mobile MVI concept may be used, which is intended to support on-demand localized operations wherever they may occur.

Area

Pre-Positioned at strategic locations across the Commonwealth

Use Case

On-Demand Emergency Response



MVI Strategy

Medium-Range Mobile

9.4.4 Example Technology Selection for Use Case 4 – Commercial Delivery

Based on the unmitigated risks associated with Commercial Delivery operations in a suburban environment, along with the Use Case specific operational requirements, the following technologies may be used:

Table 12: Example Commercial Delivery Use Case Technology Selection

Identified Risk or Operational Requirement	Technology
Cooperative crewed traffic awareness	ADS-B in receiver
UAS traffic awareness	RID reader
Real-time, location-specific weather monitoring and reporting	Micro Weather sensor
Non-cooperative crewed traffic awareness	Long-Range Fixed-Site Radar Sensor
Secure C2 communications for BVLOS flight	Licensed band C2 network
Multi-User access and deconfliction services	Software solution for sensor track fusion, display, and alerting, and UAS to UAS deconfliction scheduling and alerting.

The technology selection for the Commercial Delivery Use Case may also include airspace surveillance, RID readers and weather detection and reporting sensors, although greater in ability than those required for other example Use Cases due to the greater distances and volume of operations involved. This Use Case may also require licensed band C2 solutions to enable BVLOS flight and mitigate against any interference, especially with multiple concurrent UAS operations in a defined airspace volume. Software platforms may be used to enable multiple user access to sensor and other data, as well as fuse sensor tracks and provide situational awareness displays and alerting.

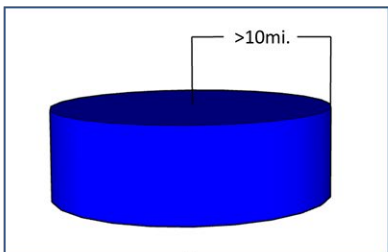
These type operations would benefit from a Long-Range Fixed-Site MVI concept, which is intended to support large area, multiple user operations.

Area

Suburban residential areas and shopping centers

Use Case

Multiple commercial operations



MVI Strategy

Long-Range Fixed-Site

10.0 Hypothetical Performance Narratives

These hypothetical performance narratives illustrate how the AAM use cases detailed above could unfold for public benefit when supported by appropriate technology and risk mitigations.

10.1 Hypothetical Performance Narrative - DFR

A busy police precinct receives a 911 call about an individual believed to be in possession of a weapon in a public space. Typically, the only information the precinct would have in advance would be from third-party reports through the dispatcher, which may not be adequate or detailed enough to support responsible decision-making.

In this case, however, the precinct can dispatch a DFR unit in advance of the responding officer's arrival. The location is uploaded to the UAS flight planning software while the RPIC completes a preflight checklist, including verification that the location is within the authorized flight area and the airspace surveillance sensors do not show any alerts.

The UA is launched and flies autonomously to the preprogrammed location, hovering at a safe distance and altitude to transmit live audio and video to both the precinct and the responding officers. The RPIC monitors the UA telemetry and airspace surveillance sensor data while other officers monitor the audio and video. The high-resolution video makes it clear that the suspect is not holding a weapon, and the responding officers arriving on the scene modify their response appropriately. The UA may remain on scene to monitor the situation if needed to ensure safety or return home for landing and recharging.

10.2 Hypothetical Performance Narrative – Medical Delivery

A parent in a rural area calls 911 because their child is suffering a severe allergic reaction to an insect bite. It will take an ambulance about 14 minutes by road to reach the child's remote location — a delay that may push the emergency into life-threatening territory.

To get the most critical support to the family as fast as possible, the EMS crew loads an EpiPen into their medical delivery UA and prepares it for dispatch. The patient's location is verified against a service area map and loaded into the flight planning software. The RPIC performs preflight checks on the UA, verifies flight approval via airspace surveillance and situational awareness tools, and launches the UA. It reaches the caller's location in less than 5 minutes — a ten-minute reduction in response time that can make the difference between treatment and tragedy.

When the UA arrives, the caller continues to receive support from EMS personnel over the phone while they retrieve and administer the EpiPen. The ambulance arrives a few minutes later, and the UA returns autonomously to the EMS station for recharging.

10.3 Hypothetical Performance Narrative – On-Demand Mobile Emergency Response

A truck transporting hazardous materials is involved in a major crash on a busy highway. There is no integrated highway monitoring infrastructure in this area, complicating assessment, coordination, and response, and traffic has backed up for miles. Assessing the scene with ground vehicles is risky because of the HAZMAT involvement, and crewed aircraft may not be available.

But in this case, VDEM has one of their Mobile On-Demand Emergency Response vehicles strategically positioned nearby. It is moved closer to the scene and becomes the anchor for an incident command post. The crew establishes an information sharing link with other agencies and begins preparing the UA, checking the operational area using the airspace surveillance sensors.

The crew launches the UA, whose pan/tilt/zoom optical sensor provides a real-time bird's eye view of the crash scene and the surrounding environment. Live images can be transmitted back to the command center and shared with other agencies and stakeholders via the data network. The camera feed from the UA shows the specific HAZMAT markings on the truck and the number of vehicles involved in the accident, allowing the emergency management teams to plan an appropriate response. The aerial imagery is also used to identify alternate roadways, which VDOT uses to dynamically reroute traffic. The response to this incident was much faster and more effective because the agencies involved were able to assess the scene quickly from a safe distance and coordinate seamlessly with each other to address it.

10.4 Hypothetical Performance Narrative for Example Use Case 4 – Commercial Delivery

The popularity of online shopping has sent more and more delivery vehicles chugging into suburban residential areas, ferrying packages from retailers' local warehouses to customers' front doors. This increased reliance on ground transportation clogs traffic, increases CO_2 emissions, and puts pressure on aging roadways.

In one metro area with sprawling suburbs, a large national retailer partnered with a UAS delivery company to deliver packages under 5 pounds (which account for most of their last-mile orders).

In one of the service areas, a father is working from home when his kids arrive home from school with a couple of extra friends in tow. The kids want their friends to stay for dinner, but he's short a few ingredients to feed this larger group. He opens up the retailer's app to place an order, and selects the "drone delivery" option. At the UAS launch and recovery site stationed at one of the retailer's locations, a worker places the items in the delivery package and loads it onto the aircraft, which autonomously flies to the delivery location. Multiple deliveries are running simultaneously, the routes safely separated from each other by the company's traffic management software. The ADS-B requirement in the airspace around this large city allows the delivery operation to safely deconflict with crewed traffic, as well.

Less than ten minutes after the order was placed, the drone zooms into view over the family's yard. The kids — who had been monitoring the flight path on the dad's smartphone — run out to see the aircraft lower its package to the designated drop spot and fly away.

11.0 Rules, Policy, and Standards Discussion

This section will focus on the regulatory implications of design, setup, and use of the MVI as it pertains to the identified use cases and geographical areas they will serve. Policies and regulations at the local, state, and federal level will be examined to determine where buy-in and approval will be needed under existing frameworks and industry standards, or through creation of new approval mechanisms.

Table 13: Summary table of applicable rules and regulations for example use cases

Use Case / Rule/Policy	DFR – urban	Med delivery – rural	Emergency resp.– strategic	Commercial delivery – suburban
14 CFR Part 77				X
14 CFR Part 157				X
AC 91-36D	X	X	X	X
AC 150/5070-6B				X
49 U.S.C. § 47107(a)				X
EB105				X
4VAC5-30-400	X	X	X	X
Virginia HB 742	X	X	X	X
14 CFR Part 21				X
14 CFR Part 89	X	X	X	X
14 CFR Part 107	X	X	X	
14 CFR Part 91	X	X	X	X
14 CFR Part 135				X
49 U.S.C. § 40102	X	X	X	
49 U.S.C. § 40125	X	X	X	
49 U.S.C. § 44806	X	X	X	
49 U.S.C. § 44807				X

11.1 Rules and Regulations Pertaining to Developing MVI

This section outlines the rules, regulations, and policies that may be applicable for the development of MVI, including those implemented and enforced by Federal, State, and Local governments. In some cases, this includes excerpts from the Federal aviation regulations contained in Title 14 of the Code of Federal Regulations, but also includes related Advisory Circulars, Bulletins, and relevant FAA forms and documents. At the State and Local level, this may include excerpts from the Code of Virginia and House Bills, however individual local ordinances may need to be verified based on specific site locations. These rules may be most applicable to construction of MVI assets, particularly within an airport environment.

11.1.1 Federal

14 CFR Part 77 – Safe, Efficient Use, and Preservation of the Navigable Airspace[31]

14 CFR Part 77 contains requirements for notifying the FAA of certain proposed construction or alterations, standards for determining obstructions to air navigation, the process for aeronautical studies related to obstructions, and the process to petition the FAA for review of determinations. Potential structures involved in the use cases that would require notice could be construction of vertiports other AAM infrastructure facilities at airports.

14 CFR Part 157 – Notice of Construction, Alteration, Activation, or Deactivation of Airports[32]

14 CFR Part 157 concerns notifying the FAA of any proposed construction, alteration, activation, and deactivation of airports. Implementation of vertiports, both on and off airports, would require notification to the FAA under Part 157. Vertiport construction and placement could also cause subsequent changes to the traffic pattern, altitude, or direction depending on the approach paths.

Advisory Circular (AC) 150/5070-6B[33]

AC 150/5070-6B provides guidance on airport master plans, which are a comprehensive study of an airport and usually describe the short-, medium-, and long-term development plans to meet future aviation demands. Airports looking for federal funding to add facilities and infrastructure must update their Airport Layout Plan (ALP) to reflect these projects.

Engineering Bulletin EB105 – Vertiport Design[34]

Engineering Bulletin EB105 specifies design guidance for public and private vertiports and vertistops, including modification of existing helicopter and airplane landing facilities, and establishment of new sites.

[31] https://www.ecfr.gov/current/title-14/chapter-I/subchapter-E/part-77
[32] https://www.ecfr.gov/current/title-14/chapter-I/subchapter-I/part-157
[33] https://www.faa.gov/airports/resources/advisory_circulars/index.cfm/go/document.current/documentnumber/150_5070-6
[34] https://www.faa.gov/sites/faa.gov/files/eb-105-vertiports.pdf

11.1.2 State

Code of Virginia 4VAC5-30-400

4VAC5-30-400 prohibits the operation of UAS within Department of Conservation and Recreation (DCR) properties in Virginia (including State Parks and Natural Area Preserves).

Virginia HB 742

Virginia HB 74 states, "*a political subdivision may, by ordinance or regulation, regulate the take-off and landing of an unmanned aircraft, as defined in § 19.2-60.1, on property owned by the political subdivision…*"

11.2 Rules and Regulations Pertaining to Use of MVI

This section outlines the rules, regulations, and policies that may be applicable for the use of MVI as implemented and enforced by the Federal Aviation Administration. This includes excerpts from the Federal Aviation Regulations contained in Title 14 of the Code of Federal Regulations for items including aircraft certification and use, associated elements, right of way rules, and waiver and exemptions.

11.2.1 FAA vs. State and Local Regulation of UAS

The FAA Office of the Chief Counsel and the US Department of Transportation Office of the Chief Counsel have jointly released an updated Fact Sheet[35] that addresses legal considerations surrounding any State or Local laws regarding UAS that may be subject to federal preemption. Specifically, these guidelines describe the UAS preemption framework as follows:

- States and local governments may not regulate in the fields of aviation safety or airspace efficiency but generally may regulate outside those fields.
- A state or local law will be preempted if it conflicts with FAA regulations.
- State or local laws affecting commercial UAS operators are more likely to be preempted.

11.2.2 Part 89

14 CFR Part 89 – Remote Identification

14 CFR Part 89 governs the use of remote identification for UAS. Remote identification will involve the broadcast of specific information by the UAS, such as a unique identifier, UAS location and speed, and UAS take-off location. By September 16, 2023, no person may operate an uncrewed aircraft within the National Airspace unless the operation meets remote identification requirements. There are three ways UAS operators can comply with the remote identification rule (Figure 61) – the UAS has remote identification built-in, the UAS has an after-market remote identification broadcast module attached, or the UAS does not have remote identification but is operating inside an FAA-Recognized Identification Area (FRIA).

[35] https://www.faa.gov/sites/faa.gov/files/State-Local-Regulation-of-Unmanned-Aircraft-Systems-Fact-Sheet.pdf

Figure 61: Three ways of complying with Part 89 Remote ID rules. Standard RID is the only option for operating Beyond Visual Line of Sight. Source: FAA UAS Remote Identification. https://www.faa.gov/uas/getting_started/remote_id

11.2.3 Part 107

14 CFR Part 107 – Small Unmanned Aircraft Systems[36]

14 CFR Part 107 governs small, unmanned aircraft system operations of drones weighing less than 55 pounds and flown within visual line of sight in the National Airspace.

14 CFR Part 107 Subpart D – Operations Over Human Beings

14 CFR Part 107 Subpart D details regulations pertaining to operations over people and moving vehicles. The UA utilized in the use cases must meet the requirements of Category 1, 2, 3 or 4 and not maintain sustained flight over any moving vehicles or boats (Table 14).

Table 14: 14 CFR Part 107 Subpart D Operations Over Human Beings and Moving Vehicles requirements and allowances for Categories 1-4 aircraft.

Category	Flight Over Non-Participating People?	Non-Sustained Flight Over Open-Air Assemblies	Sustained Flight Over Open-Air Assemblies?	Flight Over Moving Vehicles?
1	Yes	Yes	Yes, w/ RID	Non-sustained only
2	Yes	Yes	Yes, w/ RID	Non-sustained only
3	Non-sustained only	No	No	Non-sustained only
4	Yes	Yes	Yes, w/ RID	Non-sustained only

[36] https://www.ecfr.gov/current/title-14/chapter-I/subchapter-F/part-107

14 CFR Part 107 Subpart E – Waivers

14 CFR Part 107 Subpart E details a list of Part 107 regulations that are subject to waiver. Any operations that are intended to be performed outside of normal Part 107 regulations must approved by the FAA via waiver application, including beyond visual line of sight operations.

11.2.4 Part 91

14 CFR Part 91.113[37]

14 CFR Part 91.113 defines the requirement for each person operating an aircraft to both see and avoid other aircraft. This section also defines the rules surrounding which aircraft have right of way over others, and which situations take precedence in terms of applicability of precedence.

11.2.5 Part 135

14 CFR Part 135[38] contains regulations pertaining to air carrier and operator certification, and commuter and on-demand (also known as charter) operating requirements in the National Airspace. Part 135 air carrier certification is currently the only path for small UAS to carry the property of another for compensation beyond visual line of sight.

11.2.6 United States Code

49 U.S.C § 40102[39]
49 U.S.C § 40102(a)(41) describes a "public aircraft" as an aircraft used only for the United States Government, except as provided in section 40125(b).

49 U.S.C § 40125
49 U.S.C § 40125(b) further clarifies that any UAS described in section 40102(a)(41) does not qualify as a public aircraft under such section when the aircraft is used for commercial purposes or to carry an individual other than a crewmember or a qualified non-crewmember.

49 U.S. Code § 44803 – Unmanned Aircraft Test Ranges[40]
44803 defines the requirements of the Administrator of the Federal Aviation Administration to carry out and update, as appropriate, a program for the use of the test ranges to facilitate the safe integration of unmanned aircraft systems into the national airspace system, including the authority to waive certain requirements.

49 U.S. Code § 44806 - Public unmanned aircraft systems[41]
44806 defines the requirement of the Secretary of Transportation to issue guidance regarding the operation of a public unmanned aircraft system. This includes a streamlined process for issuing a Certificate of Authorization (COA) or waiver and defining a public agency's responsibilities when operating a UAS.

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[37] https://www.ecfr.gov/current/title-14/chapter-I/subchapter-F/part-91/subpart-B/subject-group-ECFRe4c59b5f5506932/section-91.113
[38] https://www.ecfr.gov/current/title-14/chapter-I/subchapter-G/part-135?toc=1
[39] https://www.faa.gov/uas/public_safety_gov/drone_program/public_aircraft_operations
[40] https://uscode.house.gov/view.xhtml?path=/prelim@title49/subtitle7/partA/subpart3/chapter448&edition=prelim
[41] https://uscode.house.gov/view.xhtml?path=/prelim@title49/subtitle7/partA/subpart3/chapter448&edition=prelim

For the purposes of operating an unmanned aircraft in the National Airspace system in support of public safety missions, there currently are two programs the public agency can utilize:

- Under 14 CFR Part 107 as a civil operation.
- As a public aircraft operator flying missions under an approved COA.

The FAA can also issue two different types of COAs:

- Day and night operations of a UAS weighting less than 55 lbs. within Class G airspace, at or below 400 above the ground within visual line of sight of the aircraft within the CONUS of the United States.
- A Jurisdictional COA that is for any weight UAS within a specific operating area that may include controlled airspace (Class D, Surface Class E, Class C or Class B).

Other operations and provisions may also be approved through the waiver application process where applicable or required for operational effectiveness.

49 U.S. Code § 44807 - Special authority for certain unmanned aircraft systems[42]

44807 grants the Secretary of Transportation the authority to use a case-by-case risk-based approach to determine if certain unmanned aircraft systems and/or operations may be conducted safely outside of 14 CFR Part 107 requirements. Specifically, this may be used to approve operations involving UAS that exceed the 55 lb. weight requirement of 14 CFR Part 107.3 or those operations that require exemptions outside of those listed in 14 CFR Part 107.205 as waiverable.

Table : Summary of Part 107 & 44806 and 44807 COAs.

	Aircraft Requirements	Pilot Requirements	Airspace Requirements	Types of Operations
Part 107	Under 55 lbs.	Remote Pilot Certificate	Class G, unless authorized or waived. See 107.41	Visual line of sight, below 400ft AGL, not over people, etc.
Section 44806 Public COA	Public aircraft only	As defined in COA	As defined in COA	As defined in COA
Section 44807 Civil COA	As required in the Exemption	Part 61 or Part 107 Certificate	Class G with airport distance requirements	As defined by the exemption, but typically for UA over 55lbs. and/or ops that can't be completed within the provisions of Part 107

[42] https://uscode.house.gov/view.xhtml?req=granuleid:USC-prelim-title49-section44807&num=0&edition=prelim

11.3 Industry Standards

There are several standards organizations that are developing standards for uncrewed aircraft and advanced air mobility. The two largest organizations are ASTM and RTCA. While these standards are not normally mandated by rules, they represent the leading industry consensus on performance and design, and in most cases, conformance satisfies regulatory approval safety concerns.

11.3.1 ASTM

The American Society for Testing and Materials (ASTM) is an international standards organization that has developed and published over 12,000 voluntary consensus standards that operate globally and covers a wide range of materials, products, systems, and services.

ASTM Committee F38 on Unmanned Aircraft Systems addresses issues related to design, quality acceptance tests, and safety monitoring for unmanned air vehicle systems. The following are F38 subcommittees and relevant active titles:

- F38.01 Airworthiness

Table 15: ASTM UAS Airworthiness standards. Source: ASTM International - https://www.astm.org/products-services/standards-and-publications.html

Standard	Description
F2910-14	sUAS Design and Construction
F2911-14e1	sUAS Production
F3002-14a	C2 Design
F3003-14	sUAS Quality Assurance
F3005-14a	sUAS Batteries
F3201-16	UAS Software
F3269-17	Bounding UAS Flight Behavior w/ Complex Functions
F3298-19	sUAS Design, Construction, Verification
F3322-18	sUAS Parachute Specifications
F3389/F3389M-20	sUAS Impact Testing
F3442/F3442M-20	DAA Performance Requirements
F3478-20	Durability and Reliability Process Dev

- F38.02 Flight Operations

Table 16: ASTM UAS flight operations standards. Source: ASTM International - https://www.astm.org/products-services/standards-and-publications.html

Standard	Description
F2849-10 (2019)	UAS at Divert Airfields
F2909-19	Continued Airworthiness
F3178-16	ORA
F3196-18	Seeking BVLOS Approval
F3411-19	RID

- F38.03 Personnel Training, Qualification and Certification

Table 17: ASTMUAS personnel training, qualification, and certification standards. Source: ASTM International - https://www.astm.org/products-services/standards-and-publications.html

Standard	Description
F2908-18	Unmanned Aircraft Flight Manual (UFM)
F3266-18	Training Guide for RPIC Endorsement
F3330-18	Training and Manual Development
F3341/F3341M-20a	Standard Terminology
F3364-19	Independent Audit Program for UAS Operators
F3365-19	ASTM Compliance Audits
F3366-19	General Maintenance Manual (GMM)
F3379-20	Public Safety Training

11.3.2 RTCA

RTCA (formerly known as Radio Technical Commission for Aeronautics) is a US non-profit that develops and publishes guidance for government regulatory authorities and industry. RTCA develops Minimum Operating Performance Standards (MOPS) for aviation-related technology to include airport security and counter UAS detection. The following are published MOPS relevant to this report:

Table 18: RTCA UAS industry standards. Source: RTCA https://www.rtca.org/standards/

Standard	Description
DO-366A	MOPS for Air-to-Air Radar for Traffic Surveillance
DO-381	MOPS for Ground-Based Surveillance System (GBSS) for Traffic Surveillance
DO-362A	Command and Control (C2) Data Link Minimum Operational Performance Standards (MOPS) (terrestrial)
DO-365A	MOPS for Detect and Avoid (DAA) Systems

11.4 Rules and Standards Specific to Example Use Cases

The rules, regulations, and standards discussed in this section apply to the four use cases in varying capacities and applications. For each example use case, the rules/regulations/standards listed are not meant to be a complete list but are highlighted as those that would require the most consideration.

11.4.1 Rules and Standards for Example Use Case 1

This operational context examines a Police Precinct in an urban city environment utilizing a Drone as a First Responder use case, conducting BVLOS operations while utilizing detect and avoid technology. A likely approach to flight authorization would come through a Public Certificate of Authorization (COA) per 49 USC § 44806, allowing for a public agency such as a law enforcement agency to conduct UAS operations under the rules and regulations described in 14 CFR Part 91. Operating under Part 107 is an option as well, but a Public COA will provide more flexibility by allowing operations that exceed Part 107 provisions. Right-of-way rules contained in Part 91.113 would need to be followed, and UAs will need to comply with remote identification requirements as outlined in Part 89. In order to mitigate air risk, this use case would need to consider detect and avoid technologies that should comply with industry standards described in ASTM F3442 and RTCA DO-365A/DO-366A/DO-381.

11.4.2 Rules and Standards for Example Use Case 2

This operational context examines a Fire/EMS Station in a rural area utilizing a Medical Delivery use case, conducting BVLOS operations while utilizing detect and avoid technology. Given that Fire/EMS responders are categorized as public agencies just like law enforcement agencies, the likely approach to operational authorization would come through a Public COA per 49 USC § 44806 while adhering to the rules and regulations described in 14 CFR Part 91, with Part 107 as an option. Adherence to right-of-way rules contained in Part 91.113 would be required, and UAs will need to comply with remote identification requirements as outlined in Part 89. Detect and avoid technologies needed to mitigate air risk should comply with industry standards described in ASTM F3442 and RTCA DO-365A/DO-366A/DO-381.

11.4.3 Rules and Standards for Example Use Case 3

This operational context examines State Emergency Services Agencies using a Statewide deployment of AAM assets for an On-Demand Emergency Response use case. As with Use Cases 1 and 2, these state emergency services agencies could operate through a Public COA per 49 USC § 44806 while adhering to the rules and regulations described in 14 CFR Part 91, with Part 107 as an option. Adherence to right-of-way rules contained in Part 91.113 would be required, and UAs will need to comply with remote identification requirements as outlined in Part 89. Detect and avoid technologies needed to mitigate air risk should comply with industry standards described in ASTM F3442 and RTCA DO-365A/DO-366A/DO-381.

11.4.4 Rules and Standards for Example Use Case 4

This operational context examines Local Businesses and Commercial UAS operators in a suburban residential and shopping area utilizing a Commercial Delivery use case. The most likely avenue to conduct operations for a commercial delivery mission is to pursue a Part 135 certificate which allows carriage of property for compensation or hire. Adherence to Part 91 general operating and flight rules would be required as these rules apply to all civil aircraft regardless of the mission (personal, for hire, passenger carrier, cargo). This use case can benefit from the same detect and avoid industry standards as the other use cases - ASTM F3442 and RTCA DO-365A/DO-366A/DO-381. Given the suburban operating environment, a review of Engineering Brief 105 on vertiport design could yield added value to the location of UA launch and recovery facilities, and vertiport construction potential to impact the National Airspace System would require a review of Part 77 as well as FAA Advisory Circular 91-36D. If vertiport development takes place on existing airport property, a review of Parts 77 and 157 as well as FAA Advisory Circulars 150/5070-6B along with US Code 47107(a) would be advisable regarding construction activities that impact the National Airspace System.

12.0 T&E Ranges & Validation Environments

The AAM industry is still in its early stages and will require significant test and evaluation (T&E), as well as validation activities, to become reality. T&E is needed to mature technology and inform rulemaking, and validation activities will need to be conducted post-rulemaking in order to demonstrate compliance with FAA requirements or Means of Compliance (MoCs). In many cases there will need to be supporting infrastructure to enable safe operations and required test points during these technology maturation and compliance testing activities.

Establishing T&E ranges early, along with providing state investment and incentives, has been shown by states such as NY and ND as a robust pathway to attracting champion operators and key technology providers. This early activity is critical to securing the ecosystem components and businesses required to make the Commonwealth a leading location for this emerging AAM market. The Commonwealth of Virginia has several key characteristics making it a prime location to establish and/or expand existing AAM test and validation ranges. These characteristics include:

- The state's geographic diversity includes mountains, coastline, dense urban, and rural regions. This diversity benefits from a wide variety of AAM use cases and can attract a corresponding variety of MVI approaches, technology providers, and early adopters.
- Situated close to Washington DC. The close proximity to decision makers in the nation's capital is an often-undervalued aspect but is immensely important when the need arises to present technology and infrastructure initiatives in front of the regulators, legislators, and decision makers.
- Virginia is home to the Virginia Tech Mid-Atlantic Aviation Partnership, a FAA UAS Test Site, FAA Beyond Partner, and FAA ASSURE member. MAAP has developed a solid and trusted relationship with the FAA, UAS standards bodies, and across the UAS industry. MAAP has established a leading position in test and validation of AAM technologies and is a go-to resource for FAA, NASA, and commercial research. MAAP can be a key asset in vetting and aligning technology partners and early adopters, gaining FAA participation and funding, and in conducting and providing oversight for MVI projects during scoping and validation phases.

Virginia already has an impressive array of environments that serve formally or informally as test ranges for sUAS research and testing. The Virginia Tech Mid-Atlantic Aviation Partnership, officially designated by the FAA as a UAS test site, offers permissions and facilities that can support a range of research activities and has a long track record of enabling industry firsts. In Hampton Roads, the confluence of a busy port, general aviation airport, urban environment, and nearby NASA facility creates numerous opportunities for research integrating next-generation autonomous systems into existing transportation infrastructure. The controlled airport at Blackstone already hosts uncrewed test operations along with its regular crewed traffic and supports both military and civilian operations. Other military installations offer protected airspace that could potentially support advanced testing not permitted or advisable in open airspace. Test ranges operated by MITRE and the NASA Langley Research Center present additional possibilities. Supplementing the resources already available in these environments with thoughtfully selected infrastructure will attract AAM companies seeing well-equipped test and validation environments.

Crucially, these facilities cover a range of landscape characteristics including varied geographies and population densities. When considering MVI for AAM research, it is advantageous to distribute investments across diverse environments to increase the likelihood of a match between sponsors' research needs and test range capabilities. For example, rural areas, where low population density reduces ground risk, are ideal for research with larger, heavier airframes and the ideal proving ground for middle-mile applications like regional air mobility. In contrast, urban areas present an opportunity to evaluate technology in a more physically and electromagnetically complex environment and test applications that will ultimately be deployed in those landscapes — urban air mobility, for example.

12.1 Example of T&E Range Enabling Real-World Approvals

In October of 2020, Raytheon responded to an FAA Broad Agency Announcement (BAA) with a whitepaper describing a scalable, multifunctional aviation and weather surveillance approach to enabling UAS Traffic Management. In partnership with two integration and data dissemination providers, a weather service provider, and the Virginia Tech Mid-Atlantic Aviation Partnership, Raytheon aimed to test the concept of creating a scalable ground-based supplemental data service, inclusive of non-cooperative aircraft and remote weather sensing. The overarching objective of this effort was to obtain data and information through demonstrations and tests related to the implementation of scalable UTM services that expand operations beyond visual line of sight, have the potential for full operational capability, and ensure the safety and security of all aircraft.

In mid to late 2022, a series of four test conducts were performed in Blacksburg, Va. Test Conducts 1 to 3 exercised various components of the system to aid in integration and verify the system prior to the final demonstration event, Test Conduct 4. During Test Conduct 4 the team demonstrated the radar and surveillance SDSP with a live fixed wing and rotorcraft intruder and demonstrated the weather SDSP functionality. During Test Conduct 4, the team flew 108 UAS flights and performed 81 encounters between the intruder and UAS. Overall, the GBSS system worked well in the test environment. During testing the surveillance SDSP alerted the operators as expected and the weather SDSP provided the information required. A review of the avoidances performed during Test Conduct 4 shows that the surveillance SDSP provided sufficient information to achieve an acceptable ASTM Near Mid-Air Collision risk ratio. This testing proved that the system's performance is sufficient to build a safety case around.

The FAA recently announced[43] its acceptance of safety case documents from UPS Flight Forward utilizing the Raytheon Skylar radar system and concept tested at the MAAP UAS Test Site to enable BVLOS operations in several states. This is just one of many real-world examples of how critical test, evaluation, and validation work performed at test sites contributes to the overall advancement of the AAM industry, and highlights the importance these sites play in obtaining regulatory operational approval.

[43] https://www.faa.gov/media/70421

13.0 Data Collection, Safety Case Development, and FAA Approval

Phase 1 of the MAAP Safety Case Development Process was used as a guide to explore the research areas needed for further planning various example UAS use cases across the Commonwealth. This included establishing a baseline for airborne use cases, and building upon that foundation by exploring potential risk areas along with likely risk mitigation strategies that included compliance with rules, standards, and procedures, and use of applicable technology. As the next logical planning step, Phase 2 of the MAAP Safety Case Develomment Process (Figure 62) would be to validate the use cases and risk mitigation strategies identified in Phase 1 through teting and demonstrations.

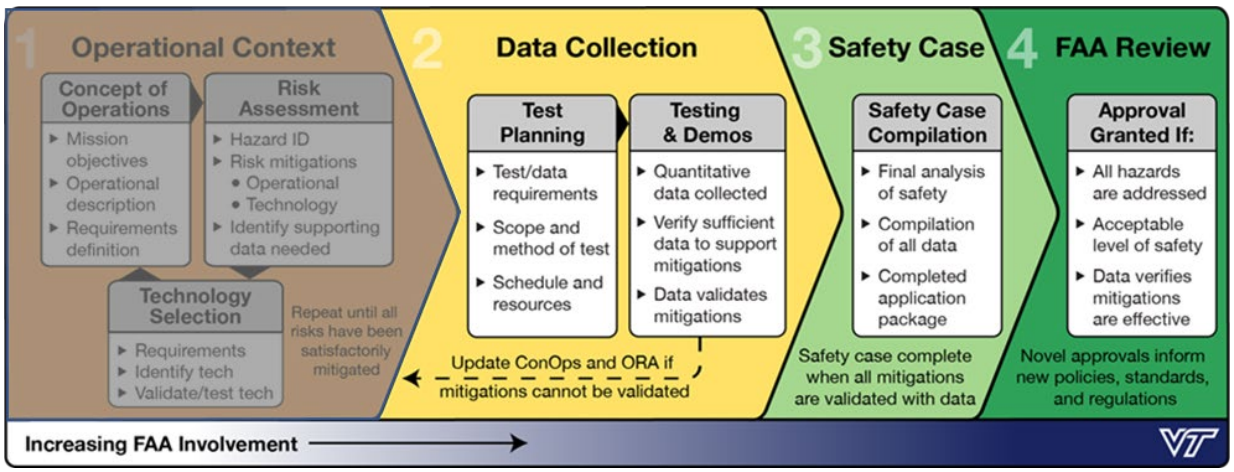


Figure 62: Phases 2 thru 4 of the MAAP Safety Case Development Process.

13.1 Data Collection

The second phase of the MAAP Safety Case Development Process is Data Collection. This phase is critical for testing and verifying how each of the identified technologies conforms to use case, regulatory, and standards requirements. As each individual technology component is verified, all components and related procedures can then be tested as a complete system for overall validation. The objective of Phase 2 is to build upon the research and outcomes from Phase 1 by testing and validating the down-selected technology within a developed concept of use framework.

13.1.1 Sensor Characterization

In following the MAAP safety case development process, the technology examples used in Section 9 above will need to be characterized for performance in accordance with industry standards discussed in Section 11.3. This process begins with test planning, which provides details on test preparation, execution, safety procedures, data capture, data analysis and documentation necessary for the safe and efficient execution of the test series. These tests may include general aviation flights being flown through the proposed airspace surveillance sensor volume with the intent to characterize sensor performance.

Data collected from the characterization process is then used to assess the sensor performance, including developing a sensor model which includes the estimated performance values varied across the surveillance volume. The sensor model, models of proposed UAS ownship, and models of the expected intruders can then be used in a MAAP developed simulation to determine the overall effectiveness against ASTM standards. Finally, additional testing may be conducted to validate the simulation results. Figure 63 below illustrates the MAAP airspace surveillance sensor characterization process.

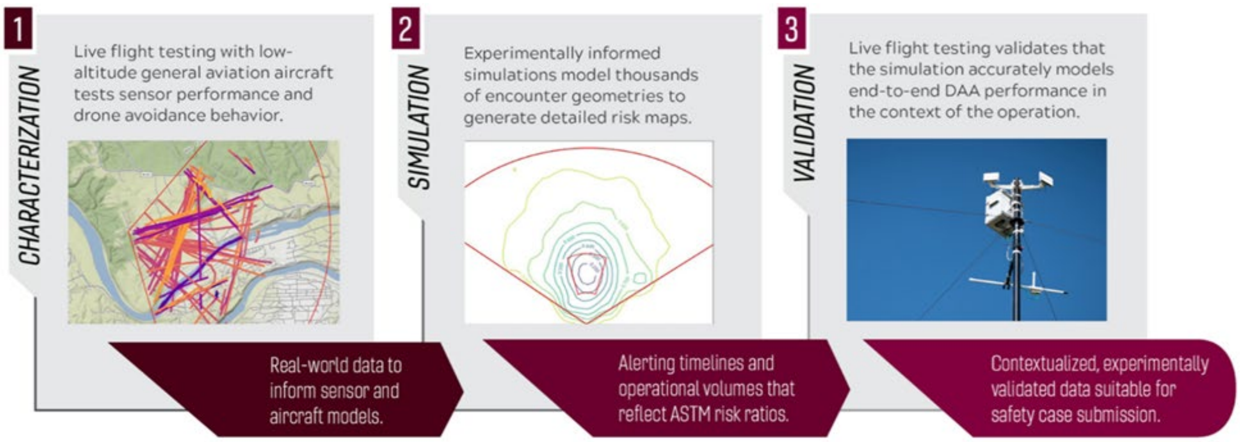


Figure 63:Details of the MAAP DAA characterization process.1) Live flight testing to characterize sensor performance, 2) Simulation models to determine appropriate risk ratios, 3) live flight testing to validate simulation results.

13.1.1.1 Test Planning

Test Planning starts with understanding the desired end state. Any technology that are desired or are mandatory aspects of the operation will be identified, along with their corresponding regulations and/or accepted standards. The Test Planning fully characterizes the entire operation along with identified technology to establish which tests are required to obtain compliance, certification, and regulatory approval. In addition to individual technology component testing, the system as a whole will be tested to verify the entire solution meets requirements and satisfactorily mitigates the identified safety hazards.

13.1.1.2 Test/Data Requirements

Each individual technology component selected for the desired operation may be separated into a category as defined as either Ground Risk, Air Risk, or Security Risk, along with the regulation and/or accepted industry standard it must comply with for use. Each use case specific requirement may be identified, along with minimum acceptable standards in terms of workflow, human factors, and technology capability. The operation as a whole can be evaluated in terms of identified hazards and potential mitigation strategies. All available data may be gathered that supports compliance from OEM’s if available. If data is not available or not sufficient to demonstrate compliance with regulations, standards, requirements or safety hazard mitigations, testing or demonstrations may be recommended.

13.1.1.3 Scope and Method of Test

The scope and method of testing or demonstrations may be determined by the delta between the available data and the data needed to satisfy the regulation, standard, or requirement. This may include collaboration and input from technology OEMs, as well as Federal, State, and Local government stakeholders.

13.1.1.4 Testing and Product Demonstrations

Testing may be performed on identified technology as required to satisfy regulatory and or standards requirements, as well as verify safety hazard mitigations. For systems that have previously conformed to regulatory and or standards requirements and provide sufficient test data and documentation, demonstrations may be conducted in lieu of testing to verify performance. Each individual component may be tested or demonstrated separately as it pertains to a specific risk area and its respective criteria. Additionally, the entire system as a whole may be tested to ensure it conforms to the requirements and satisfies all safety hazard mitigations.

13.1.1.5 Quantitative Data Collected

Quantitative data can include technology performance as compared to established regulations and standards. Examples include airspace surveillance sensor performance in terms of number of false tracks vs. actual detects, and the resulting risk ratios that either meet established standards or not. The data collected is intended to inform on performance by testing or demonstrating specific, measurable attributes of the technology. The data should be collected in as real-world scenario as possible, meaning the data should be collected in a way that mimics how it will ultimately be used.

13.1.1.6 Verify Sufficient Data to Support Mitigations

The results of the testing or demonstrations should provide sufficient data as to whether or not the technology and or method of use was effective in meeting regulations, standards, requirements or safety hazard mitigations. If there are any gaps in the data or unanswered or unaddressed areas, Test Planning and Testing and Demos may be reiterated until all necessary data is collected.

13.1.1.7 Data Validates Mitigations

The final step in the Data Collection process is to verify the collected data successfully mitigates all compliance, requirement, and safety concerns. Full system validation may be conducted to verify the end-to-end solution's ability to satisfy all aspects of the identified requirements.

13.2 Safety Case Development & Regulatory Approvals

Step one of the Safety Case Development Process provided a complete description of the operation, including how people and technology will work together., while Step two demonstrated how the technology is characterized and tested against current industry accepted standards to prove an acceptable level of safety is achieved. The Third step begins by identifying the method of regulatory compliance required and presents the data from steps one and two in the appropriate format.

Certain operations may be conducted by rule, such as conformance to 14 CFR Part 107, 49 U.S.C. 44806 or 44807, for which there are clear expectations concerning operators, equipment, and operational boundaries for each. In these cases, safety case development may entail documentation that proves conformance with the established guidelines these rules provide. In the case of 44806 and 44807 approvals, the FAA has established an application process that entails a comprehensive operational and technical review where the applicant is required to provide all details of their intended operation and the technology they will utilize.

For operations that require approvals outside of established rules, a waiver or exemption may be requested. In these cases, the onus is on the applicant to demonstrate to the regulator how their operations will maintain an equivalent level of safety while operating outside of established rules. This is typically accomplished through the Data Collection process detailed in Section 13.1 and comparing the test data against established industry standards. FAA Designated UAS Test Sites like Virginia Tech's Mid-Atlantic Aviation Partnership are well positioned and experienced in performing these type tests and associated analysis and reporting to enable advanced AAM use cases for both public and private entities.

13.3 Safety Case and Regulatory Approval Specific to Example Use Cases

Regardless of use case or regulatory approval pathway, every proposed UAS operation will require validation of the procedures and required technology as part of the Safety Case Development process. This section provides examples specific to each of the four identified use cases.

13.3.1 Data Required and Approval Process for Example Use Case 1 (DFR)

The DFR use case may likely choose to operate under a Public COA as described in Section 11.2.6 as Public Aircraft Operations. In this case, the public agency would submit an application to the FAA that fully describes the intended operation, including the flight operations area, operations plan, UAS specifications, and any flight crew qualifications. In addition, the COA application may require the following attachments:

- The public declaration letter that declares the public agency's public aircraft status
- An airworthiness statement from the agency's accountable executive declaring the UAS(s) they are operating is airworthy and that they will maintain an airworthiness program
- A lost link document for each UAS that explains the loss of link protocol for the UAS
- A loss of communication document that describes the loss of communication between the Remote Pilot in Control (RPIC) and their observer, and the loss of communication between the PIC and air traffic control if that is required
- An emergency procedures document that lists the different emergencies an operation may have and how the public agency will respond to such emergencies.

If BVLOS flight or any other advanced operations that may require waiver or special approval is requested for the operations, test data would need to be submitted that answers questions on technology performance in accordance with one or more of the industry standards described in Section 11.3 as it relates to the use case and location specific requirements.

13.3.2 Data Required and Approval Process for Example Use Case 2 (Medical Delivery)

A Medical Delivery use case may have the option to operate under 49 U.S.C. 44806 as a public aircraft operation, and/or under 14 CFR Part 107, depending on their specific operational requirements. This type use case may also include the public agency contracting public aircraft operations to a private entity on their behalf. For strictly public operations, the data requirements and approval mechanisms may be similar to the DFR use case. If a certificate of waiver is required for operations under Part 107, additional data will be needed that addresses specific questions concerning any technologies and/or procedures that are used to enable those operations. Traditionally, this may be accomplished by following the steps outlined in the MAAP Safety Case Development Process, including:

- Full description of the operational concept
- Risk mitigation strategy
- Test data proving how any technologies being used conform to accepted industry standards

The FAA has provided a list of Part 107 waiver safety explanations guidelines[44] and guiding questions that must be addressed when submitting a waiver request IAW 14 CFR Part 107 Subpart E Waivers.

13.3.3 Data Required and Approval Process for Example Use Case 3 (Mobile Emergency Response)

An On-Demand, Mobile UAS Response use case will likely gain operational approval through the process outlined under 49 U.S.C. 44806. In this case, a "blanket COA" may be more appropriate over a specific jurisdictional COA, as it may provide operational authority across the entire state vs limited to a specific area. For emergency response operations that require special provisions that are not included in the COA, the FAA has created a Special Governmental Interest (SGI) process. The SGI process is an expedited approval mechanism that aims to quickly approve UAS operations for first responders and other organizations responding to natural disasters or other emergency situations, including:

- Firefighting
- Search and Rescue
- Law Enforcement
- Utility or Other Critical Infrastructure Restoration
- Damage Assessments Supporting Disaster Recovery Related Insurance Claims
- Media Coverage Providing Crucial Information to the Public

To apply for a waiver through the Special Governmental Interest (SGI) process, the applying entity must either be an existing Part 107 remote pilot with a current certificate OR a public agency with

[44] https://www.faa.gov/sites/faa.gov/files/107WSEGsandGQs-06-23-2023-TOC.pdf

an existing Certificate of Waiver or Authorization (COA). If the public agency is requesting an SGI under their COA, they must operate a UAS that is either owned by the public agency or leased to the public agency for a minimum of 90 days.

13.3.4 Data Required and Approval Process for Example Use Case 4 (Commercial UAS Delivery)

A Part 135 certification is the only path for small drones to carry the property of another for compensation beyond visual line of sight. The FAA's existing Part 135 certification process has been adapted for drone operations by granting exemptions for rules that don't apply to drones, such as the requirement to carry the flight manuals on board the aircraft. The FAA issues air carrier certificates to U.S. applicants based on the type of services they plan to provide and where they want to conduct their operations. Operators must obtain airspace authorizations and air carrier or operating certificates before they can begin operations. A standard Part 135 air carrier certificate contains a stipulation that operations must be conducted in accordance with the provisions and limitations specified in its Operational Context documentation.

In addition to the UA specific requirements, these type operations may be operationalized through the UTM methodology described in Section 4.3.2, *UTM Architecture*, and Section 9.1.2 *UTM Model*. Since UTM operates as a data exchange, the primary means of communication and coordination between Operators, the FAA, and other stakeholders is through a distributed information network similar to what is proposed in the MVI concept. Some services provided by USSs, like airspace surveillance or licensed band communications require qualification by government agencies such as the FAA or FCC in order to support Operators in meeting applicable regulations and policies. In this case, any required technologies would need to be characterized to demonstrate conformance with applicable laws and standards, and how they may enable the proposed operations.

The FAA has published a UTM Concept of Operations v2.0[45] that outlines the foundational principles and roles and responsibilities associated with implementation.

[45] https://www.faa.gov/sites/faa.gov/files/2022-08/UTM_ConOps_v2.pdf

14.0 Community Sentiment and Buy-In

One of the features that distinguishes AAM from traditional crewed aviation is its relatively close and routine interaction with the public. Today, most people engage directly with aviation primarily as passengers on commercial airliners, trips whose expense makes them relatively infrequent. AAM will introduce many new points of contact. Consider small UAS applications: In some cases, these will be safer, cheaper alternatives to activities currently executed by crewed aircraft, such as infrastructure inspections, emergency response, and public safety missions. The much greater feasibility of conducting these operations via UAS means that they will become much more common than the analogous crewed flight. In other cases, activities traditionally handled via ground transportation, such as delivery of small packages, will be shifted to aircraft.

As integration of these applications moves forward, it will become routine for members of the public to receive deliveries by drone (or see their neighbors' deliveries) or observe small drones being operated by public safety or law enforcement agencies; more and more people will be employed by organizations leveraging this technology, or become remote pilots themselves. Further in the future, people will interact directly with AAM as passengers on urban air mobility services.

This close engagement with the public situates effective outreach and education at the core of successful AAM integration. For applications like package delivery and urban air mobility that involve direct consumer interaction, public acceptance will determine commercial viability. In cases where these aircraft are being used as tools by law enforcement and other organizations, perception of the technology will influence perception of, and trust in, those organizations and affect their ability to effectively serve the public good.

Successful public engagement efforts help decision-makers develop an accurate, nuanced understanding of public perception and community needs, and help communities understand the features and capabilities of AAM technology and how it will be deployed in their communities. This bidirectional flow of data and insight can inform future AAM implementation, positioning new initiatives for success by shaping them to serve the needs and address the concerns of a receptive public.

To achieve these goals for the AAM initiatives outlined in this report, we propose a two-pronged approach: First, a deliberate, targeted community outreach program adapted to each project; and second, where possible, systematic studies of public perception over time.

14.1 Community Outreach

The Commonwealth of Virginia led one of the most successful teams in the FAA's UAS Integration Pilot Program (IPP), and has continued that work through the agency's successor BEYOND program. Both programs had an explicit focus on community engagement as a key pillar of implementing real-world UAS applications, offering an opportunity for the IPP and BEYOND partners — in particular the Virginia Tech Mid-Atlantic Aviation Partnership and drone delivery company Wing — to develop and validate a successful community engagement framework. This framework provides a useful template for future AAM community engagement, which can be tailored to the specific communities and operations under consideration.

Community engagement activities can fall into several categories, covered in more detail below. Targeted stakeholder engagement lays a strong foundation for subsequent outreach. Broader public outreach efforts create an ongoing dialogue and build familiarity. Smaller, goal-oriented programs for specific audiences, such as STEAM programs for K-12 students, provide additional educational and enrichment opportunities, demonstrate investment in the community, and help build a pipeline for workforce development.

14.1.1 Stakeholder engagement

The first step of a successful community engagement program should be the identification of and early outreach to key stakeholders. These will be individuals and groups who are influential in and knowledgeable about the community, as well as groups likely to be directly impacted by any proposed operations (*e.g.* town council, law enforcement, airport authority, etc.). Collaborating with these parties early in the process 1) builds collaborative relationships with key public figures; 2) provides valuable information regarding likely public sentiment, potential concerns, and productive outreach strategies; and 3) ensures that community officials are well-equipped to answer questions from their constituents. This cultivates buy-in by being attentive to and respectful of existing structures of influence, and allows individuals who have already earned the public's trust to become advocates for new programs.

This early stakeholder engagement is foundational to the success of any subsequent outreach, and is another virtue of approaching this work through public-private partnerships. For OEMs and operators developing and deploying AAM applications, partnerships with state and local government organizations provide an invaluable access point to existing stakeholder networks and source of community knowledge, dramatically expediting and increasing the efficacy of the process of building trust in the community. For public organizations, these partnerships provide an opportunity for them to offer added value and new services to their constituents and expand their local economies.

14.1.2 Public engagement

Once that bedrock of stakeholder relationships has been established, broader public outreach will be much more effective. While some segments of the general public may already be familiar with certain AAM technologies and applications, exposure and awareness will likely vary. Prior to the implementation of any MVI-related initiatives, particularly those that will be highly visible to the public, it is that the organizations involved plan a comprehensive and well-coordinated informational program characterized by unified messaging and clear, concise information that can be distributed through a variety of channels. The goal is a high-touch approach that provides the public with repeated opportunities both to encounter key information and to make connections with program personnel who can answer questions and provide avenues for additional follow-up.

Vehicles for this type of outreach include existing public meetings and events; events specifically created around these projects, and owned and earned media. When possible, these activities should include participation from local stakeholders and allies who can help establish legitimacy and communicate, both directly and indirectly, that these efforts are being conducted in consultation and partnership with communities. Community partners are also a valuable source of guidance on the selection of appropriate venues for this outreach, and should be consulted whenever possible.

These proactive outreach activities should also be used explicitly to solicit feedback and questions from the public, which has proven to be an effective way to gauge general sentiment and to identify specific areas of enthusiasm or concern. This information can help guide subsequent outreach and educational efforts, allowing the organizations involved to craft an outreach strategy, and ultimately an operational approach, that is responsive to community needs and concerns. Communicating clear interest in and receptiveness to feedback will help engender trust and goodwill, invaluable commodities in the potential deployment of any new technology.

This basic approach will apply to all four use cases under consideration. However, each will be perceived by the public as having unique advantages and disadvantages, which should be reflected in the content and focus of the associated community outreach plan. The second and third use cases, which both involve emergency response, are likely to be most readily accepted by the public. Because the concept of operations for the use of drones for emergent medical deliveries will require some participation from witnesses, an educational campaign informing the public about how to engage with these services will be essential. However, we anticipate the response to these applications to be largely positive.

The first and fourth use cases will present more public perception challenges. The DFR use case, which involves the use of drones by law enforcement specifically for surveillance, is likely to raise concerns about privacy. Members of the community may be concerned about where the drones are flying, what imagery they are capturing, and how it will be used. The community outreach plan should include potential responses to these concerns – including that drones will only be used in response to calls, as extensions of patrol officer activities, not to perform ongoing surveillance. Messaging on these issues should be clear, consistent, and as informative as possible.

Transparency — to the extent that it is consistent with the effective practice of law enforcement — can be a helpful counterbalance to these concerns. The groundbreaking DFR program run by the city of Chula Vista, California includes an extensive website providing detailed information about the program, including historical data and flight paths when appropriate. The free provision of this information has helped build trust and acceptance for a new program. DroneResponders, a 501(c)3 non-profit public safety program, has published a guide[46] for public safety agencies to help guide the development of a DFR program. Residential package delivery has generally been received positively in communities. However, in communities new to this technology, there are likely to be misconceptions about safety, privacy, and regulation. As in the DFR use case, these should be proactively addressed with clear and consistent messaging. Residents may also be concerned about noise, particularly in quiet suburban communities; it is helpful in these conversations to provide a reference point for the level of sound produced by the drone, and examples of manufacturers' efforts to mitigate this issue.

The most compelling perceived benefit of drone delivery seems to be convenience. However, other positive aspects that can be emphasized in outreach include reduced traffic, lower carbon emissions, and expanded markets for local businesses.

Encouragingly, public outreach conducted through the IPP and BEYOND has generally demonstrated that transparency and education regarding current or proposed UAS technology, operations, and regulation has tended to promote increased public comfort with and receptiveness

[46] https://www.droneresponders.org/_files/ugd/e60acc_b8b5e91b307f42319ebb92212d051672.pdf

towards the technology. While the specific content and degree of public acceptance may vary for different programs, it is nevertheless clear that a proactive educational campaign offers the best window into public sentiment and the most promising path towards public acceptance.

14.1.3 K-12 STEAM Programming

Educational programming for K-12 students is another avenue through which both organizations involved in AAM initiatives can engage productively with communities. Partnerships between aircraft or technology manufacturers and school systems or local governments can support robust, well-funded programs that allow the company to become more deeply integrated into the community and build positive relationships; these programs can also serve as a workforce development pipeline that, over time, will nurture the AAM industry in the community and promote economic development. Meanwhile, the municipality is able to offer enhanced services to students, including those from underserved populations who may not otherwise have had opportunities to work closely with this technology.

One example of an initiative of this type is a drone camp for underserved middle school students developed by Virginia Tech in partnership with Wing. The camp has now been run for two summers in Blacksburg and inspired an analogous version at the Innovation Campus in Alexandria. The weeklong camp, during which students build their own drone and learn about a variety of aspects of the industry, has received exceptionally positive reviews from the campers and been seen by all the institutions involved as an asset to their missions.

14.2 Public Perception Research

While outreach events and other forms of direct engagement yields meaningful and actionable insights about public attitudes towards a proposed or ongoing operation, the most rigorous tool for evaluating sentiment, the factors that influence it, and how it changes over time is the large population survey. High-quality surveys on public perception provide crucial context for legislators, regulators, and community leaders as they consider introducing new technologies. Evidence-based analysis of perceived advantages and risks can inform effective outreach strategies, help companies design services that will engender enthusiasm and acceptance, and build public trust – all necessary conditions for the technology to afford its greatest possible benefit.

To be reliable, these surveys should be rigorous and multidisciplinary, incorporating relevant technical, cultural, and policy expertise. The Virginia Tech Mid-Atlantic Aviation Partnership has led large-scale surveys evaluating public sentiment towards drone delivery, partnering with researchers from the university's departments of statistics and science, technology, and society. The first project, in October 2020, surveyed Christiansburg, Va. residents a year after the launch of Wing's drone delivery service. This was a unique opportunity to study a community that routinely experienced drone delivery, and the results were extremely encouraging: 87% of respondents reported positive sentiment.

These results demonstrated the value of a quantitative, methodologically rigorous approach in understanding community sentiment towards drone delivery. Similar efforts would help guide AAM integration. For example, being able to quantitatively compare public perception of each of the four example use cases would yield valuable information about the ultimate viability of these services. Surveys conducted across communities deploying similar operations could reveal community characteristics that influence sentiment. All of this information can inform future decisions about where, and how, to implement new services for the maximum social and economic benefit.

This research is resource-intensive, and often prohibitively expensive. However, where feasible, public-private partnerships can make these projects possible, coupling the financial resources of a private company with the neutrality of a public agency. Robust data on these questions will support an approach to UAS integration at the national and community scale that is grounded in strong situational awareness. Careful attention to community acceptance will maximize the potential rewards for companies, state and local governments and economies, the regulator, and, most importantly, for the communities the technology is designed to serve.

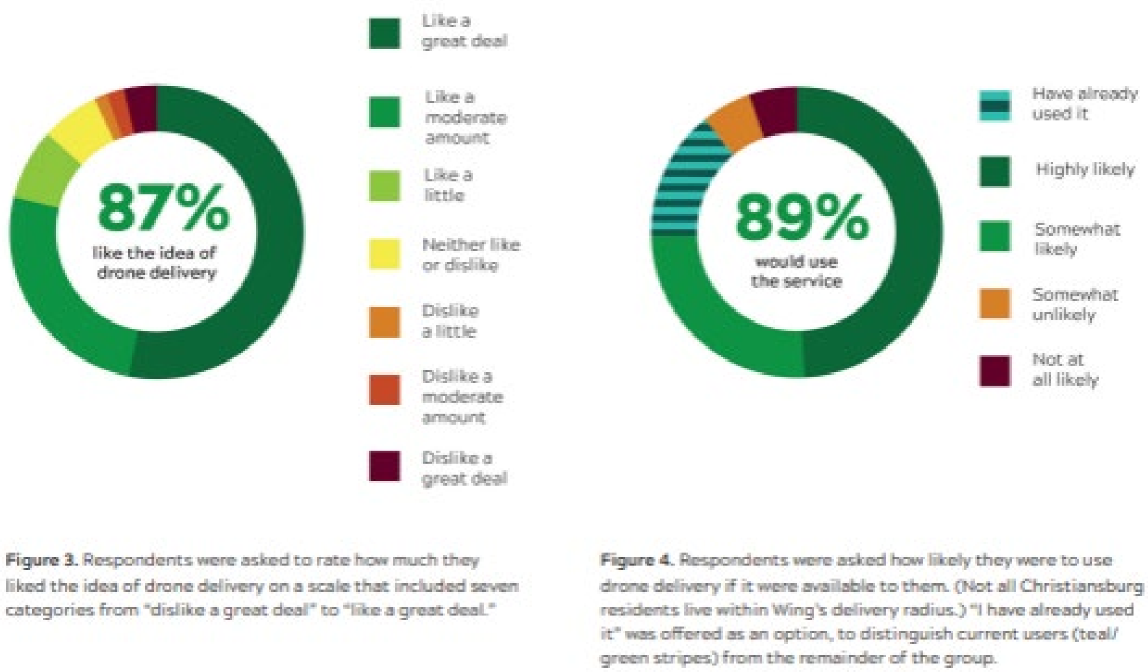


Figure 64:Excerpt from a Virginia Tech/Wing Aviation public perception survey conducted in the Christiansburg, Va. area in reference to drone delivery service. (See Appendix B)

15.0 MVI Economic Model Discussion

With input from DOAV and other stakeholders, potential business models for use of MVI will be examined to evaluate economic feasibility in terms of initial investment, number of people and areas served, and Return on Investment (ROI), with the goal of providing a template for working with Commonwealth communities to determine economic viability and investment priority. Examples of data being examined may include capital cost per square mile of coverage, amount of money saved through implementation of use cases, potential savings of operations and maintenance costs, decrease in safety related incidents and associated costs, and number of jobs created. Building upon the Metrics of Benefits in Table 1, Demonstrations of Economic Viability may be assigned to each benefit to gain a more in-depth understanding of how a proposed Use Case may financially be self-sustaining.

Table 19: Example ROI types

Use Case	Metrics of Benefit	Demonstration of Economic Viability
Drone as a First Responder	Reduced Dispatch	Measure reduction in dispatch and the benefit in terms of reduced stress of force / need to hire (e.g., Chula Vista reduction in dispatch of 24% [47]) at average cost $48,000 per head per year[48]
	Reduced Time to Dispatch	Reduction in dispatch time improves public satisfaction and safety, and reduces need for additional resources (e.g., Chula Vista DFR response average of 115 seconds compared to 6-7 minutes for conventional response)
	Change in Modality	Shift from Ambulance to Medical Transport (ambulance running upwards of $1,000 per call [49],[50] while medical transport is below $500 per call)
	Harm Reduction	Ability to reduce risk of escalation in law enforcement encounters; ability to provide life-saving goods quickly can reduce risk of death and harm in

[47] https://www.chulavistaca.gov/departments/police-department/programs/uas-drone-program
[48] https://www.ziprecruiter.com/Salaries/What-Is-the-Average-Police-Officer-Salary-by-State
[49]https://www.fairfaxcounty.gov/fire-ems/sites/fire-ems/files/assets/documents/pdf/emt/ems_transport_flyer largeprint.pdf
[50] https://www.albemarle.org/government/fire-rescue/ambulance-billing/ems-cost-recovery

Use Case	Metrics of Benefit	Demonstration of Economic Viability
		emergency medical (reduce hospital stays can save over $2,000 per day) [51],[52]
Government and Utility Inspection and Monitoring	Time and Cost Savings	Reduction in inspection time and savings in personnel or contractor cost (reducing time and cost by factors of 2x – 5x) [53]
	Failure Prevention	Increasing inspection frequency allows for hazards and failures to be identified early
	Post Event Assessment Safety	Post extreme weather events or HAZMAT incidents, drones can provide situational intelligence without risking harm to first responders and inspectors [54]
Logistics	Commercial Value	Time savings in delivery of time-critical goods, such as power grid, aviation, and utility components (substation outages can cost customers hundreds of dollars per hour) [55]
	Medical Harm Reduction	Delivery of medical goods remotely can improve compliance and health, reducing ER visits and hospital stays (compliance can significantly reduce ER visits, by over 20% in diabetics; further interventions that reduce hospital stays can save over $2,000 per day) [56],[57]
	Middle-Mile Value	Expansion of regional logistics networks through UAS can accelerate delivery of goods to local communities while lowering the cost of business for logistics companies

[51] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7954858/
[52] https://www.kff.org/health-costs/state-indicator/expenses-per-inpatient-day/?currentTimeframe=0&sortModel=%7B%22colId%22:%22Location%22,%22sort%22:%22asc%22%7D
[53] https://www.power-eng.com/om/8-ways-drones-are-lowering-the-cost-of-infrastructure-inspection/#gref
[54] https://www.power-technology.com/features/cleaning-up-nuclear-waste-robotics/?cf-view
[55] https://www.semanticscholar.org/paper/Electric-Power-Distribution-System-Reliability-and/adab2578f02daa57b631fb47af9a0e851b4a26b0
[56] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7954858/
[57] https://www.kff.org/health-costs/state-indicator/expenses-per-inpatient-day/?currentTimeframe=0&sortModel=%7B%22colId%22:%22Location%22,%22sort%22:%22asc%22%7D

Use Case	Metrics of Benefit	Demonstration of Economic Viability
Test Ranges	Economic Development Value	Supports training and workforce development
Other Commercial	Survey and Videography Time and Cost Savings	Reduce survey and videography time by 5-10x [58] in addition to development of new commercial entities and high-tech jobs
	Agricultural Cost Savings and Yield Improvement	Ability to conduct more cost-effective and timely crop monitoring can assist with weed management, water management, and crop biomass tracking [59]
	RAM and UAM Services Value, Economic Development	Ability to develop new passenger air service at sustainable cost; can revitalize depressed communities – estimated economic benefit of passenger air service.

15.1 Cost Estimation and Sustainability

Metrics of benefit may also be combined with cost estimation of installing and operating MVI to determine if the use case and infrastructure are sustainable. This allows the locality to develop a sustainability model to determine potential return on investment and revenue neutrality of the infrastructure. The ROI / Sustainability model has six major components representing cost and benefit:

- Costs
    1. Capital Expenditure Costs (costs of acquisition, installation, and integration of infrastructure and sensors)
    2. Up Front Costs (training and program implementation, development of safety case)
    3. Operational Costs (equipment, personnel and subsidies, if needed)
    4. Operations and Maintenance (leasing costs of equipment, refresh, operation of equipment)
- Benefit
    5. Calculation of Benefit (use metric of benefit to calculate benefit of service)

[58] https://govdesignhub.com/2020/02/20/how-surveying-with-drones-can-save-governments-time-and-money/
[59] https://search.nal.usda.gov/discovery/fulldisplay?docid=alma9915680814207426&context=L&vid=01NAL_INST:MAIN&lang=en&search_scope=pubag&adaptor=Local%20Search%20Engine&tab=pubag&query=any,contains,drone%20crop%20monitoring%20benefits&offset=0

6. Allocated Service Contribution / Fees (use benefit to estimate service fees to defray operating costs)

15.1.1 Sustainability Modeling

Sustainability models, including cost of acquiring, leasing, and operating MVI assets, costs of standing up (public) services, estimate of benefit, and application to funding of MVI operation may be created to determine the economic viability of enabling service. This type of model may also be used to showcases several key metrics:

- Cost per Square Mile: what is the cost of standing up the MVI assets per covered square mile?
- Cost per Covered Life: what is the cost of standing up the MVI assets per covered life?
- IRR: What is the Internal Rate of Return on the Investment?
- O&M Coverage: Does the benefit and potential savings or value cover the MVI operating cost?

Beginning in Section 15.2, templates have been created that lay out notional financial models to assess the financial sustainability of two of the example Use Case. The numbers are purely notional, but lay out a framework for costing out the MVI infrastructure, costing out program deployment and support, and estimating economic benefit to evaluate long-term program sustainability. Since these numbers are purely notional and meant to provide examples of economic model templates, only the first two example use cases were examined, with the addition of a combined model to showcase the concept of multiple use cases benefiting from a single MVI emplacement. Key components of these models include:

Initial MVI Capital Expenditures
- Initial acquisition costs of sensors and infrastructure

MVI Operations and Maintenance
- Ongoing recurring costs of operating and maintaining the MVI infrastructure

AAM Operations Upfront Costs
- The cost of establishing the AAM operations that will leverage the infrastructure

AAM Operations Ongoing Costs
- The cost of sustaining operations

Investment Return
- Identification of metrics of benefit and quantification of those metrics based on volume and value

Allocation to Service Fees
- The portion of benefits that can be used to fund operations of MVI

Key Metrics
- Such as enablement and operations costs per square mile or covered life, and internal rate of return on investment

15.2 Example DFR Business Model

Below is a notional economic analysis of implementation of a DFR program with the following operational assumptions:

- Population Density: High
- Area covered: 8 square miles
- Approx. Number of people served: 100,000
- Number of UAS assets: 3 Group 1 sUAS
- Number of FTE Pilots: 2 trained public safety officers

This would be a low-to-medium risk set of operations using a Short-Range Fixed-Site MVI approach. Public Safety can leverage public sites and communications assets, which may aid in lowering costs as compared to commercial operations.

Assuming,

- 1% of the covered population benefits from a reduction in dispatch severity
- Resultant harm reduction is realized in one-third of public safety responses
- Reduced dispatch costs of 25% of the estimated economic benefit is assigned to program and infrastructure sustainment

this case has the potential to generate an internal rate of return of 11%.

This program has lower costs and rewards which may be attributed to several factors, including lower risk threshold and program cost for DFR activities, ability to leverage existing assets, and serving a relatively large population in a relatively small area.

15.2.1 Example of Initial DFR Investment Costs

			Year 1	Year 2	Year 3	Year 4	Year 5
INVESTMENT COSTS							
MVI Capital Expenditures	Sites/Units	Cost					
ADS-B Sensor Purchase	1	$2,500	$2,500				
RemoteID Sensor Purchase	3	$3,500	$10,500				
GNSS RTK Beacon Purchase	1	$2,500	$2,500				
Weather Sensor Purchase	1	$2,500	$2,500				
Communications Equipment	3	$2,500	$7,500				
Installation	3	$500	$1,500				
Integration	1	$25,000	$25,000				
Software Purchase	1	$10,000	$10,000				
Consumables	3	$1,500	$4,500				
MVI Operations and Maintenance							
Equipment Maintenance (FTE)	0.25	$75,000	$18,750	$18,750	$18,750	$18,750	$18,750
Bandwidth	3	$500	$1,500	$1,500	$1,500	$1,500	$1,500
Software Lease / Maintenance	1	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000
Consumables	3	$500	$1,500	$1,500	$1,500	$1,500	$1,500
MVI Costs			$90,250	$23,750	$23,750	$23,750	$23,750
Upfront AAM Operations Costs / CapEx							
Vehicle Acquisition	3	$20,000	$60,000		$60,000		$60,000
Training	2	$5,000	$10,000	$2,000	$2,000	$2,000	$2,000
Safety Case Development	1	$25,000	$25,000				
AAM Operations Upfront Costs			$95,000				
AAM Operational Costs / Subsidies							
Insurance	1	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500
Vehicle Maintenance	2	$2,500	$5,000	$5,000	$5,000	$5,000	$5,000
Personnel	2	$75,000	$150,000	$150,000	$150,000	$150,000	$150,000
Ongoing AAM Operations Costs			$157,500	$159,500	$219,500	$159,500	$219,500
Total Costs							
Up Front			$185,250				
Operating			$157,500	$183,250	$243,250	$183,250	$243,250
Total Cost		***$1,195,750***					

15.2.2 Example of DFR Investment Return

			Year 1	Year 2	Year 3	Year 4	Year 5
INVESTMENT RETURN							
Calculation of Benefit							
Metric of Benefit 1 - Medical Dispatch Reduction							
Units of Service, Applicable Flights			50	250	500	1,000	1,000
Application of Benefit Realized - Savings per Dispatch			$400	$400	$400	$400	$400
Total of Benefit 1			$20,000	$100,000	$200,000	$400,000	$400,000
Allocation to MVI Services (%)			25.0%	25.0%	25.0%	25.0%	25.0%
Allocation to MVI Services			$5,000	$25,000	$50,000	$100,000	$100,000
Metric of Benefit 2 - Police/Fire Dispatch Reduction							
Units of Service, Applicable Flights			100	500	1,000	1,500	1,500
Application of Benefit - Reduced Hospitalization			$50	$50	$50	$50	$50
Total of Benefit 2			$5,000	$25,000	$50,000	$75,000	$75,000
Allocation to MVI Services (%)			25.0%	25.0%	25.0%	25.0%	25.0%
Allocation to MVI Services			$1,250	$6,250	$12,500	$18,750	$18,750
Metric of Benefit 3 - Medical Harm Reduction							
Units of Service, Applicable Flights			20	100	150	300	300
Application of Benefit - Reduced Hospitalization			$4,600	$4,600	$4,600	$4,600	$4,600
Total of Benefit 3			$92,000	$460,000	$690,000	$1,380,000	$1,380,000
Allocation to MVI Services (%)			25.0%	25.0%	25.0%	25.0%	25.0%
Allocation to MVI Services			$23,000	$115,000	$172,500	$345,000	$345,000
Total Economic Benefit			$117,000	$585,000	$940,000	$1,855,000	$1,855,000
Total Benefit		***$5,352,000***					
RETURN ON INVESTMENT - ECONOMIC VIABILITY							
Allocation of Benefit to Service Fees			$29,250	$146,250	$235,000	$463,750	$463,750
Units / Flights			170	850	1,650	2,800	2,800
Service Contribution per Flight			$172.06	$172.06	$142.42	$165.63	$165.63
Total Service Fee Contributions		***$1,308,750***					
Cash Flows		Costs	($342,750)	($183,250)	($243,250)	($183,250)	($243,250)
		Service Fees	$29,250	$146,250	$235,000	$463,750	$463,750
		Total Flows	($313,500)	($37,000)	($8,250)	$280,500	$220,500
Key Metrics							
Square Miles Covered	10	Sq. Miles					
Upfront Cost per Square Mile			$18,525.00				
Operating Cost per Square Mile			$15,750.00	$18,325.00	$24,325.00	$18,325.00	$24,325.00
Lives Covered	100,000	Lives					
Upfront Cost per Covered Life			$1.85				
Operating Cost per Covered life			$1.58	$1.83	$2.43	$1.83	$2.43
Internal Rate of Return	11%						
OM Coverage (Level of Coverage)				0.8x	1.0x	2.5x	1.9x

15.3 Example Medical Delivery Business Model

Below is a notional economic analysis of implementation of the implementation of a commercial (non-emergency) medical delivery with the following assumptions:

- Population Density: Medium
- Area Covered: 25 square miles
- Approx. Number of People Served: 50,000
- Number of UAS Assets: 3 Group 2 sUAS
- Number of FTE Pilots: 3

This would include both medium and high risk set operations using a combination of Short-Range Fixed Site MVI (for higher risk areas, such as adjacency to an airport) and Wide-Area Low-Cost MVI (cooperative with some non-cooperative for the broader area).

Assuming,

- 10% of the local population (high risk population) takes advantage of the service
- This results in a 25% reduction in ER visits and resulting hospital admissions (consistent with compliance intervention results) due to unnecessary ambulance dispatches
- 25% of the estimated economic benefit is assigned to program and infrastructure sustainment

this use case has the potential to generate an internal rate of return of 14%.

Note that commercial medical delivery to support medication and therapy compliance drives a higher benefit since ER and Ambulance visits may be avoided altogether, rather than simply reducing the necessary level of intervention. Further, since the cost baseline is commercial medical, the per-unit cost reductions are greater than the DFR (public services) case.

15.3.1 Example of Initial Medical Delivery Investment Costs

				Year 1	Year 2	Year 3	Year 4	Year 5
INVESTMENT COSTS								
MVI Capital Expenditures		Sites/Units	Cost					
	ADS-B Sensor Purchase	1	$2,500	$2,500				
	RemoteID Sensor Purchase	7	$3,500	$24,500				
	Small Radar Purchase	2	$150,000	$300,000				
	GNSS RTK Beacon Purchase	1	$2,500	$2,500				
	Weather Sensor Purchase	2	$2,500	$5,000				
	Communications Equipment	8	$2,500	$20,000				
	Installation	8	$500	$4,000				
	Integration	1	$25,000	$25,000				
	Software Purchase	1	$10,000	$10,000				
	Consumables	8	$1,500	$12,000				
MVI Operations and Maintenance								
	EO/IR Lease	4	$15,000	$60,000	$60,000	$60,000	$60,000	$60,000
	RF Sensor Lease	4	$10,000	$40,000	$40,000	$40,000	$40,000	$40,000
	Equipment Maintenance (FTE)	0.25	$75,000	$18,750	$18,750	$18,750	$18,750	$18,750
	Bandwidth	8	$1,000	$8,000	$8,000	$8,000	$8,000	$8,000
	Software Lease / Maintenance	1	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000
	Consumables	8	$100	$800	$800	$800	$800	$800
MVI Costs				$535,050	$129,550	$129,550	$129,550	$129,550
Upfront AAM Operations Costs / CapEx								
	Vehicle Acquisition	3	$100,000	$300,000		$300,000		$300,000
	Training	3	$5,000	$15,000	$2,000	$2,000	$2,000	$2,000
	Safety Case Development	1	$50,000	$50,000				
AAM Operations Upfront Costs				$365,000				
AAM Operational Costs / Subsidies								
	Insurance	1	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500
	Vehicle Maintenance	3	$7,500	$22,500	$22,500	$22,500	$22,500	$22,500
	Personnel	3	$90,000	$270,000	$270,000	$270,000	$270,000	$270,000
Ongoing AAM Operations Costs				$295,000	$297,000	$597,000	$297,000	$597,000
Total Costs								
	Up Front			$900,050				
	Operating			$295,000	$426,550	$726,550	$426,550	$726,550
Total Cost			***$3,501,250***					

15.3.2 Example of Medical Delivery Investment Return

			Year 1	Year 2	Year 3	Year 4	Year 5
INVESTMENT RETURN							
Calculation of Benefit							
Metric of Benefit 1 - Reduced Emergency Room Admissions							
Units of Service, Applicable Flights			100	500	1,000	1,250	1,500
Application of Benefit Realized - Reduced ER Visits			$1,000	$1,000	$1,000	$1,000	$1,000
Total of Benefit 1			$100,000	$500,000	$1,000,000	$1,250,000	$1,500,000
Allocation to MVI Services (%)			25.0%	25.0%	25.0%	25.0%	25.0%
Allocation to MVI Services			$25,000	$125,000	$250,000	$312,500	$375,000
Metric of Benefit 2 - Ambulance Dispatch Reduction							
Units of Service, Applicable Flights			50	250	500	500	500
Application of Benefit Realized - Savings per Dispatch			$1,200	$1,200	$1,200	$1,200	$1,200
Total of Benefit 2			$60,000	$300,000	$600,000	$600,000	$600,000
Allocation to MVI Services (%)			25.0%	25.0%	25.0%	25.0%	25.0%
Allocation to MVI Services			$15,000	$75,000	$150,000	$150,000	$150,000
Metric of Benefit 3 - Medical Harm Reduction							
Units of Service, Applicable Flights			50	250	500	600	700
Application of Benefit - Reduced Hospitalization			$4,600	$4,600	$4,600	$4,600	$4,600
Total of Benefit 3			$230,000	$1,150,000	$2,300,000	$2,760,000	$3,220,000
Allocation to MVI Services (%)			25.0%	25.0%	25.0%	25.0%	25.0%
Allocation to MVI Services			$57,500	$287,500	$575,000	$690,000	$805,000
Total Economic Benefit			$390,000	$1,950,000	$3,900,000	$4,610,000	$5,320,000
Total Benefit		***$16,170,000***					
RETURN ON INVESTMENT - ECONOMIC VIABILITY							
Allocation of Benefit to Service Fees			$97,500	$487,500	$975,000	$1,152,500	$1,330,000
Units / Flights			200	1,000	2,000	2,350	2,700
Service Contribution per Flight			$487.50	$487.50	$487.50	$490.43	$492.59
Total Service Fee Contributions		***$3,945,000***					
Cash Flows		Costs	($1,195,050)	($426,550)	($726,550)	($426,550)	($726,550)
		Service Fees	$97,500	$487,500	$975,000	$1,152,500	$1,330,000
			($1,097,550)	$60,950	$248,450	$725,950	$603,450
Key Metrics							
Square Miles Covered	10	Sq. Miles					
Upfront Cost per Square Mile			$90,005.00				
Operating Cost per Square Mile			$29,500.00	$42,655.00	$72,655.00	$42,655.00	$72,655.00
Lives Covered	100,000	Lives					
Upfront Cost per Covered Life			$9.00				
Operating Cost per Covered life			$2.95	$4.27	$7.27	$4.27	$7.27
Internal Rate of Return	14%						
OM Coverage (Level of Coverage)				1.1x	1.3x	2.7x	1.8x

15.4 Example of Combined DFR & Medical Delivery Business Model

One item for consideration is that while initial infrastructure build-out should be closely targeting one or a few use cases, the DFR operations and Commercial Medical Delivery (as well as retail delivery) use cases are in many ways operationally similar, and may use the same infrastructure. Therefore, an area such as that described for Medical Delivery would almost, by default, be enabled for DFR operations. The model below considers the potential return of this combined scenario.

In this model, the MVI infrastructure costs are the same, as are base assumptions about vehicle and personnel. The covered population for the area is the same, but the area is larger, so the vehicles, pilots, and training assumptions for a DFR overlay remain the same. Additional safety case development is required because not only does each operational approach require a safety case, but commingling them requires additional analysis to assure safety. In considering the benefit, adding the DFR over the Commercial Medical Case adds additional benefits, however the availability of the Commercial Medical service and improvement in medication access and compliance should reduce the need for Emergency Medical response, so we reduced the overall expected frequency of this benefit.

The result is that by sharing common infrastructure over two use cases, and using conservative assumptions about program cost savings and additive benefit, the expected internal rate of return may potentially increase to 26%.

15.4.1 Example Initial Combined Use Case Investment Costs

	Sites/Units	Cost	Year 1	Year 2	Year 3	Year 4	Year 5
INVESTMENT COSTS							
MVI Capital Expenditures	Sites/Units	Cost					
ADS-B Sensor Purchase	1	$2,500	$2,500				
RemoteID Sensor Purchase	7	$3,500	$24,500				
Small Radar Purchase	2	$150,000	$300,000				
GNSS RTK Beacon Purchase	1	$2,500	$2,500				
Weather Sensor Purchase	2	$2,500	$5,000				
Communications Equipment	8	$2,500	$20,000				
Installation	8	$500	$4,000				
Integration	1	$25,000	$25,000				
Software Purchase	1	$10,000	$10,000				
Consumables	8	$1,500	$12,000				
MVI Operations and Maintenance							
EO/IR Lease	4	$15,000	$60,000	$60,000	$60,000	$60,000	$60,000
RF Sensor Lease	4	$10,000	$40,000	$40,000	$40,000	$40,000	$40,000
Equipment Maintenance (FTE)	0.25	$75,000	$18,750	$18,750	$18,750	$18,750	$18,750
Bandwidth	8	$1,000	$8,000	$8,000	$8,000	$8,000	$8,000
Software Lease / Maintenance	1	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000
Consumables	8	$100	$800	$800	$800	$800	$800
MVI Costs			$535,050	$129,550	$129,550	$129,550	$129,550
Upfront AAM Operations Costs / CapEx							
Vehicle Acquisition - Group 1	2	$20,000	$40,000		$40,000		$40,000
Vehicle Acquisition - Group 2	2	$100,000					
Training	4	$5,000	$20,000	$2,000	$2,000	$2,000	$2,000
Safety Case Development	1	$100,000	$100,000				
AAM Operations Upfront Costs			$160,000				
AAM Operational Costs / Subsidies							
Insurance	4	$2,500	$10,000	$10,000	$10,000	$10,000	$10,000
Vehicle Maintenance	4	$5,000	$20,000	$20,000	$20,000	$20,000	$20,000
Personnel	4	$80,000	$320,000	$320,000	$320,000	$320,000	$320,000
Ongoing AAM Operations Costs			$350,000	$352,000	$392,000	$352,000	$392,000
Total Costs							
Up Front			$695,050				
Operating			$350,000	$481,550	$521,550	$481,550	$521,550
Total Cost		***$3,051,250***					

15.4.2 Example Combined Use Case Investment Return

			Year 1	Year 2	Year 3	Year 4	Year 5
INVESTMENT RETURN							
Calculation of Benefit							
Metric of Benefit 1 - Reduced Emergency Room Admissions							
Units of Service, Applicable Flights			100	500	1,000	1,250	1,500
Application of Benefit Realized - Reduced ER Visits			$1,000	$1,000	$1,000	$1,000	$1,000
Total of Benefit 1			$100,000	$500,000	$1,000,000	$1,250,000	$1,500,000
Allocation to MVI Services (%)			25.0%	25.0%	25.0%	25.0%	25.0%
Allocation to MVI Services			$25,000	$125,000	$250,000	$312,500	$375,000
Metric of Benefit 2 - Ambulance Dispatch Reduction - Commercial							
Units of Service, Applicable Flights			50	250	500	500	500
Application of Benefit Realized - Savings per Dispatch			$1,200	$1,200	$1,200	$1,200	$1,200
Total of Benefit 2			$60,000	$300,000	$600,000	$600,000	$600,000
Allocation to MVI Services (%)			25.0%	25.0%	25.0%	25.0%	25.0%
Allocation to MVI Services			$15,000	$75,000	$150,000	$150,000	$150,000
Metric of Benefit 3 - Ambulance Dispatch Reduction - Emergency Medical							
Units of Service, Applicable Flights			25	125	200	400	400
Application of Benefit Realized - Savings per Dispatch			$400	$400	$400	$400	$400
Total of Benefit 3			$10,000	$50,000	$80,000	$160,000	$160,000
Allocation to MVI Services (%)			25.0%	25.0%	25.0%	25.0%	25.0%
Allocation to MVI Services			$2,500	$12,500	$20,000	$40,000	$40,000
Metric of Benefit 4 - Police/Fire Dispatch Reduction							
Units of Service, Applicable Flights			50	250	500	750	750
Application of Benefit - Reduced Hospitalization			$50	$50	$50	$50	$50
Total of Benefit 4			$2,500	$12,500	$25,000	$37,500	$37,500
Allocation to MVI Services (%)			25.0%	25.0%	25.0%	25.0%	25.0%
Allocation to MVI Services			$625	$3,125	$6,250	$9,375	$9,375
Metric of Benefit 5 - Medical Harm Reduction							
Units of Service, Applicable Flights			50	300	200	700	800
Application of Benefit - Reduced Hospitalization			$4,600	$4,600	$4,600	$4,600	$4,600
Total of Benefit 5			$230,000	$1,380,000	$920,000	$3,220,000	$3,680,000
Allocation to MVI Services (%)			25.0%	25.0%	25.0%	25.0%	25.0%
Allocation to MVI Services			$57,500	$345,000	$230,000	$805,000	$920,000
Total Economic Benefit			$402,500	$2,242,500	$2,625,000	$5,267,500	$5,977,500
Total Benefit		***$16,515,000***					
RETURN ON INVESTMENT - ECONOMIC VIABILITY							
Allocation of Benefit to Service Fees			$100,625	$560,625	$656,250	$1,316,875	$1,494,375
Units / Flights			275	1,425	2,400	3,600	3,950
Service Contribution per Flight			$365.91	$393.42	$273.44	$365.80	$378.32
Total Service Fee Contributions		***$4,028,125***					
Cash Flows		Costs	($1,045,050)	($481,550)	($521,550)	($481,550)	($521,550)
		Service Fees	$100,625	$560,625	$656,250	$1,316,875	$1,494,375
			($944,425)	$79,075	$134,700	$835,325	$972,825
Key Metrics							
Square Miles Covered	10	Sq. Miles					
Upfront Cost per Square Mile			$69,505.00				
Operating Cost per Square Mile			$35,000.00	$48,155.00	$52,155.00	$48,155.00	$52,155.00
Lives Covered	100,000	Lives					
Upfront Cost per Covered Life			$6.95				
Operating Cost per Covered life			$3.50	$4.82	$5.22	$4.82	$5.22
Internal Rate of Return	26%						
OM Coverage (Level of Coverage)				1.2x	1.3x	2.7x	2.9x

16.0 Consideration of Larger AAM Use Cases

Consistent with NASAs UML-2 and the FAAs Initial UAM operational descriptions, two near-term larger AAM use cases are proposed for the Commonwealth within the AAM framework: UAS Cargo Delivery and Airport Transfer. Additionally, an AAM\UAM test site and related infrastructure is proposed to incentivize industry stakeholders to invest in the Commonwealth through development of technology, procedures, and approvals.

16.1 UAS Cargo Delivery

UAS Cargo Delivery refers to autonomous movement of cargo within and between transportation hubs such as rail yards and ports, as well as from these locations out to other distribution end points. UAS cargo delivery differs from the related concept of UAS package delivery in size and weight of the payload being transported. While UAS package delivery focuses on smaller, consumer type items, UAS cargo delivery would focus on transporting larger items or multiple packages. Examples include moving cargo between distribution facilities such as Amazon and Walmart hubs, moving parts and supplies to and from manufacturing plants, and ship to shore or offshore resupply and cargo movement. UAS Cargo Delivery may have some distinct advantages over traditional over the road truck transport, including the ability to operate 24 hours a day without running into delays caused by roadwork and accidents, and sidestepping the longer wait times that trucks may encounter at docks or warehouses.

There are several business models and use cases that may be explored within the UAS cargo delivery space dependent on location (Figure 66). In western Virginia, the I81 corridor may be a prime area for the transport of goods to major hubs along the route. In eastern Virginia, several marine ports and rail yards may benefit from expedited movement of goods, including offshore deliveries to and from ships and offshore platforms.

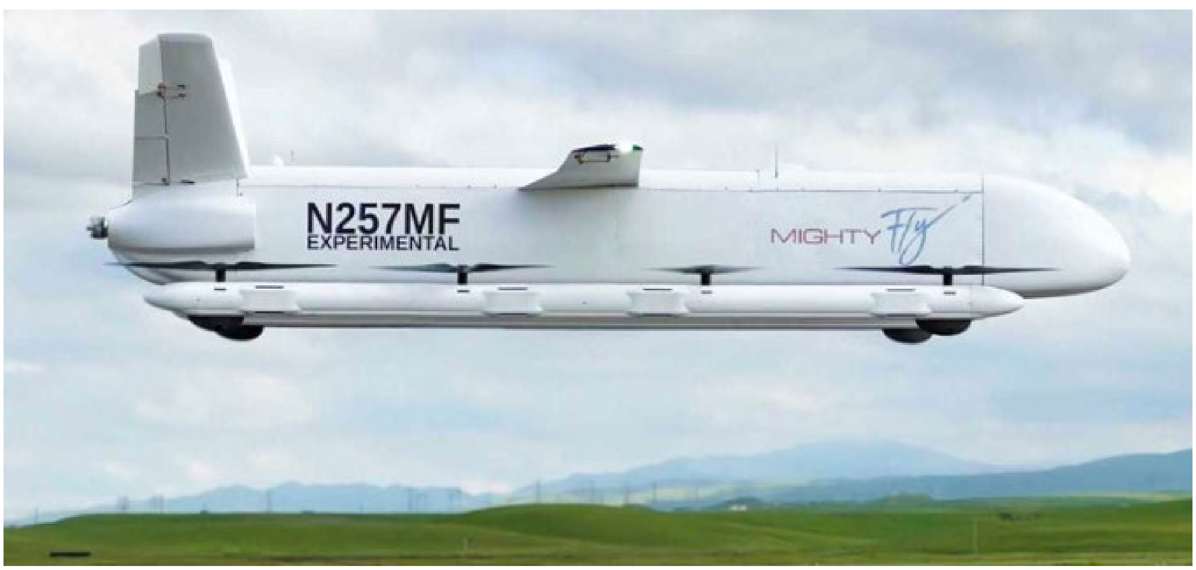


Figure 65: The Michigan Mobility Funding Platform (MMFP) has awarded MightyFly a $150,000 grant to demonstrate autonomous, fixed-wing electric vertical take-off and landing (eVTOL) aircraft cargo deliveries of 100 pounds of cargo in the state of Michigan. Source: https://mightyfly.com/press-release/2945/

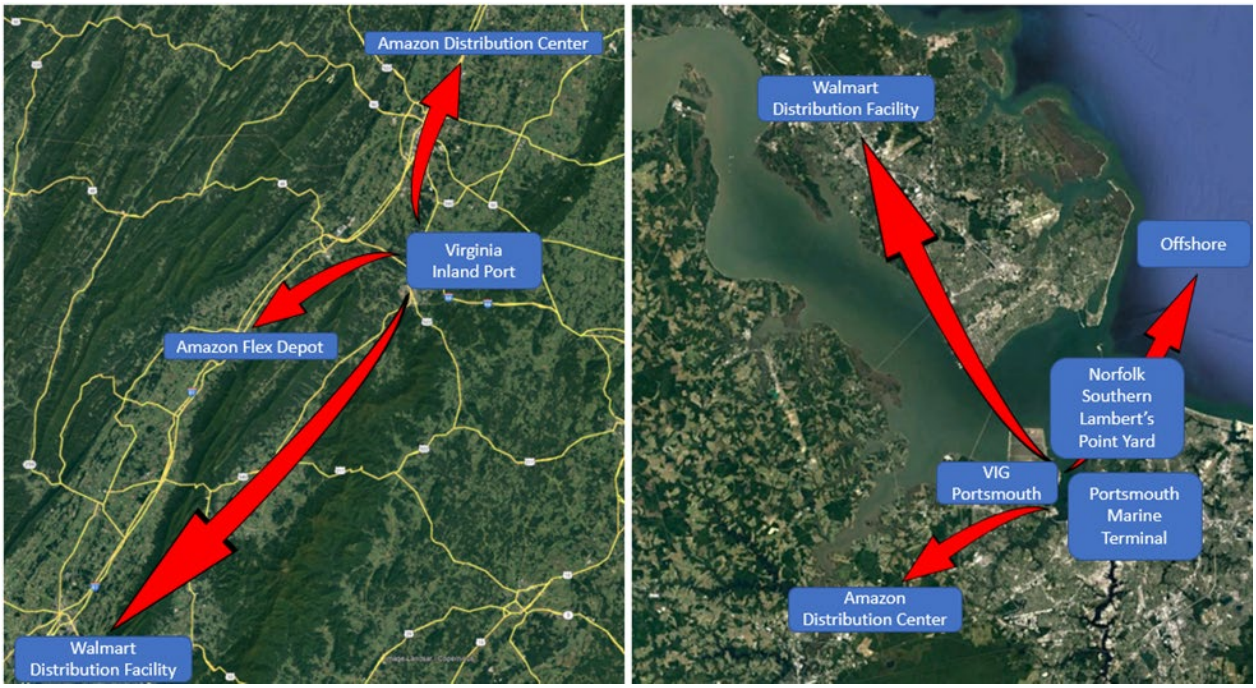


Figure 66: Examples of UAS Cargo Delivery along the I81 corridor in western Virginia (left) and around the Norfolk area (right).

16.1.1 MVI for UAS Cargo Delivery

The infrastructure requirements for UAS cargo delivery are similar to the requirements described for sUAS use cases, allowing for a fair amount of overlap depending on operational locations. Infrastructure would include a licensed band communications network that allows the RPIC to continuously know the position of their aircraft without exceeding the performance capabilities of the C2 link in terms of distance, security, and interference. In addition, an airspace surveillance solution would allow the RPIC to see non-cooperative air traffic for enabling uncrewed BVLOS operations.

16.1.2 Regulatory Considerations for UAS Cargo Delivery

Regulatory requirements for the aircraft to safely operate over people and moving vehicles include certification under 14 CFR Part 21.17(b), which provides a method for the FAA to certify special class aircraft such as UAS for which airworthiness standards have not been issued. Additionally, 49 USC 44807 grants the Secretary of Transportation authority to use a case-by-case risk-based approach for determining safe operations of UAS in the National Airspace System. This option has been used for UAS that exceed 14 CFR Part 107 weight requirements and/or require exemptions outside those listed as waiverable. Additionally, Part 135 Air Carrier would be required for aircraft carrying goods for hire. In addition to aircraft certification, a comprehensive safety case would be required for use of technology and procedures used for risk mitigation in pursuit of operational approvals, particularly in the case of uncrewed BVLOS operations. The safety case would be compiled via extensive technology characterization and subsequent validation testing of risk mitigation strategies against industry and regulator accepted standards. Approvals gained may then be used as precedent for expanded operations in other areas and use cases that utilize similar technology and methods.

Economics of UAS Cargo Delivery

In a 2022 research article published by Roland Berger, an international management consultancy firm, the cargo drone market is projected to grow to $17.9 billion by 2030 due to increased demand for expedited industrial and emergency delivery. Other market drivers and indicators include a significant increase in drone related autonomous technology patents, which have risen from around 15,000 in 2017 to almost 40,000 in 2021.

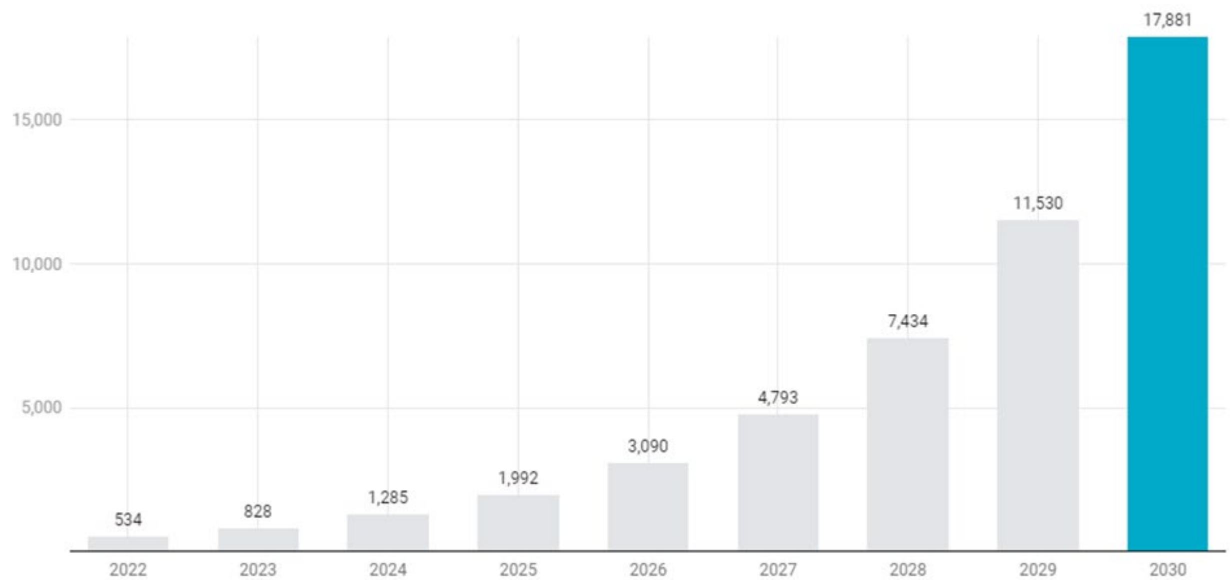


Figure 67: Chart depicting the expected growth of the UAS Cargo Delivery market through 2030. Source: Roland Berger https://www.rolandberger.com/en/Insights/Publications/Cargo-drones-A-potential-gamechanger-in-the-logistics-industry.html

In Europe, a UAS Cargo Delivery company, Dronamics (https://www.dronamics.com/) has developed an aircraft and the world's first cargo drone company in part with a $2.5 million grant from the European Innovation Council. Early figures suggest their service can deliver over 700lbs. of cargo over 1,500 miles for 50% cheaper than conventional air freight, and with 60% less carbon emissions.

16.2 Urban Air Mobility (UAM)

Urban Air Mobility refers to the expedited movement of people between existing transportation infrastructure points and to other destinations within the region. This includes travel both between traditional access points such as bus stations, train stations, airports, and ports, and also from these traditional access points to more non-traditional points such as vertiports or alternate landing sites not previously served by aviation. Examples include transporting people from outlying Executive/Municipal airports to Regional and International airports, between regional airports, or within urban areas such as from parking structures to mass transportation hubs (Figure 68, Figure 69, and Figure 70).

Figure 68: Example of UAM providing transportation between regionally located airports as an alternative to time-consuming traditional road transportation or more expensive air travel.

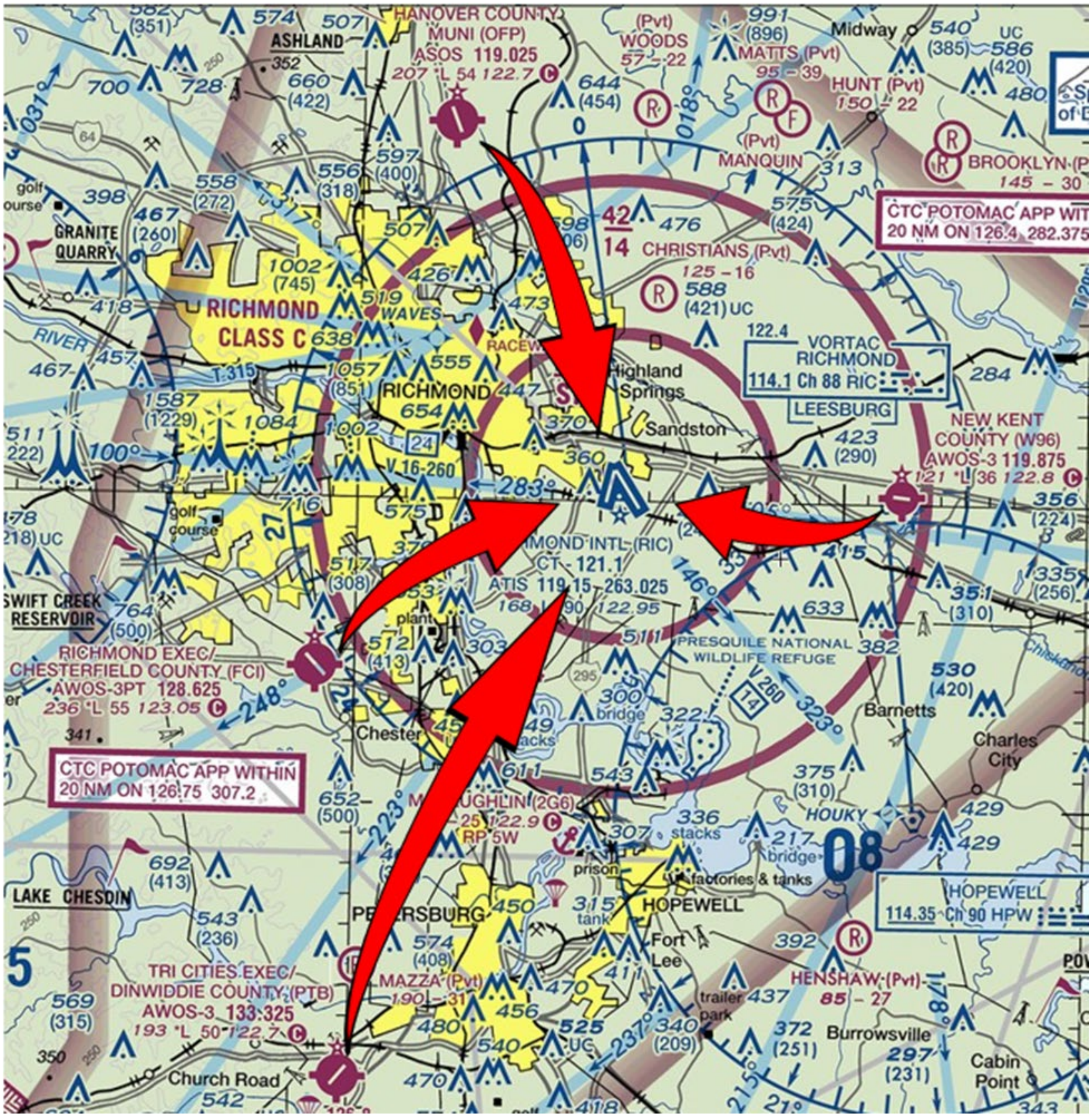


Figure 69: Example of UAM providing transportation from outlying airports to a larger hub airport.

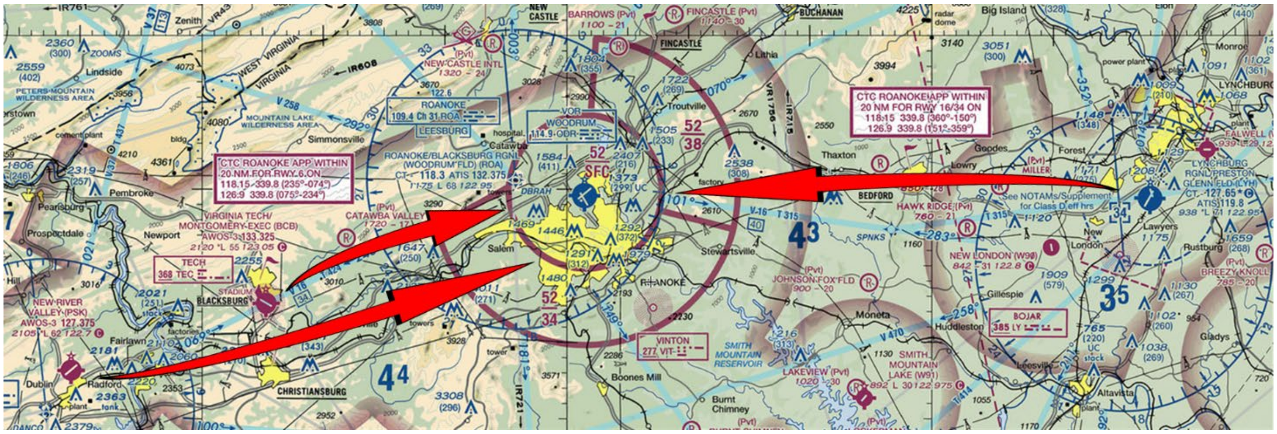


Figure 70: Additional Example of a vertiport network at smaller, outlying airports being used to transport passengers to a larger Regional airport.

Figure 71:Example of UAM eVTOL aircraft. Source: Wisk https://wisk.aero/

16.2.1 MVI for UAM

The infrastructure requirements for UAM may include development of vertiports and associated approach procedures to accommodate these aircraft, including electric charging facilities, maintenance capability, and electric propulsion specific fire containment systems. In addition, low-level airspace surveillance systems may be required in the terminal environment, such as surrounding vertiports, in order to provide UAM aircraft with self-separation capabilities with existing, non-cooperative air traffic. If operating under the Providers of Services to UAM (PSU) model where a third-party entity is providing Air Traffic and Flight Safety services to UAM aircraft, an airspace surveillance service may be ingested from a separate third party, such as a Supplemental Data Service Provider (SDSP). An SDSP providing services to a UAS Service Supplier (USS) may also be providing services to a PSU where applicable and allow for overlap of infrastructure element usage.

NAVOS Air, a Virginia-based air navigation services company authorized by the FAA to develop non-Part 97 satellite-based instrument approach approaches, was instrumental in gaining approval for the first public-use vertiport, which is located at the Allen C. Perkinson Blackstone Army Airfield (KBKT). In addition, NAVOS has developed instrument approach procedures for use by AAM aircraft utilizing the vertiport.

Per the NAVOS Air Concept document Vertiport Designations and AAM specific instrument procedures are necessary to:

1. Enable and Expand AAM NAS Operations

Provide a means to deliver AAM to airport locations, off airport locations, newly established Vertiports or Points-in-Space serving a geographic area with an equivalent level of safety and standardization consistent with conventional aircraft operations.

2. Provide Transitions To or Through ATM/UTM

Provide known and documented transitions between air traffic control sectors or systems, including future low-level systems (e.g., Uncrewed Traffic Management (UTM)) for air traffic separation, spacing and sequencing.

3. Integrate Emergent Users with Legacy Users

Safely integrate emergent NAS users with legacy users. Providing a basis for AAM IFR operations under current rules will allow participation and commerce in today's air management systems while informing future air traffic management models.

4. Enable Further Research of NAS Integration of AAM

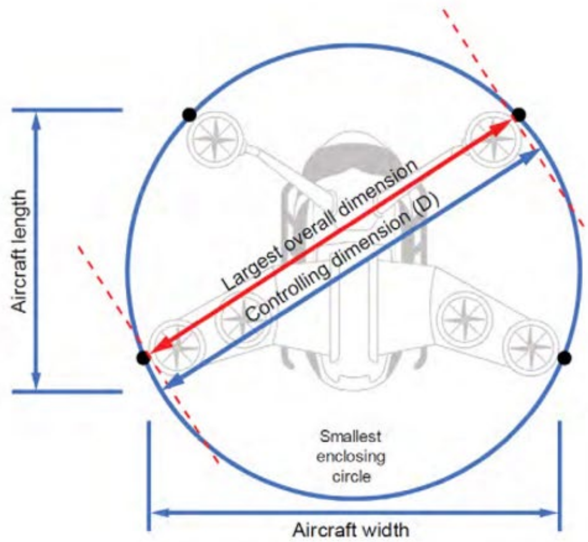
Use and modification of instrument procedures as well known and proven aviation infrastructure tools will provide NASA, FAA, and other research entities opportunities to study requirements for AAM to operate with standards of safety, reliability, performance, and certification consistent with conventional aircraft capable of operating under IFR.

5. Maximize Efficiency of Airspace Use

UAS/AAM will be more maneuverable and have different performance profiles than conventional aircraft. Procedures designed specifically for AAM flight operations and aircraft will allow smaller procedure volumes relieving air traffic congestion in terminal environments, increasing throughput and improving safety.

6. Accommodate Energy Efficiency Requirements of EVTOL/STOL Aircraft

Smaller procedure volumes and more direct routing will allow manageable flight timing and reserves



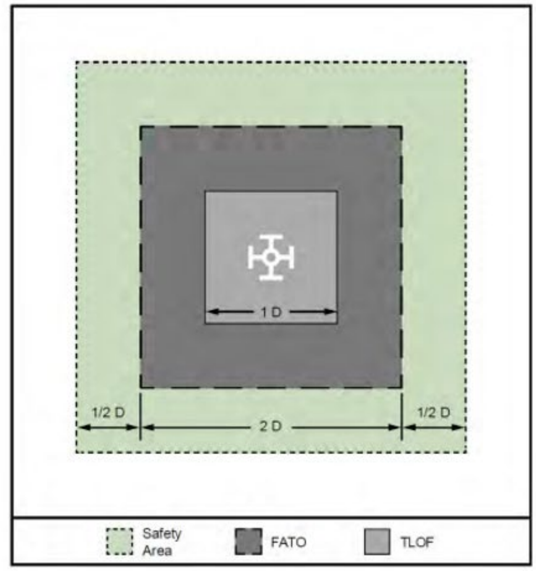


Figure 72:Excerpt from FAA Engineering Bulletin # 105 detailing the requirements for vertiport creation. Source: FAA EB#105 https://www.faa.gov/airports/engineering/engineering_briefs/engineering_brief_105_vertiport_design

In addition to vertiport and associated approach procedures, vertiport specific management systems may be required to manage on and off-airport vertiport systems and traffic. ANRA Technologies has developed a web-based Vertiport Management System (VMS) software platform to support AAM aircraft operations at newly established vertiports (Figure 73). This technology was developed to support increasing levels of autonomy in various AAM use cases for both piloted aircraft and uncrewed drones by exchanging real-time data between the aircraft and the various services needed to support arrivals and departures such as real-time vertiport resource status; flight reservation and clearance requests; flight status; live telemetry for monitoring aircraft data; micro weather services; and aircraft surveillance

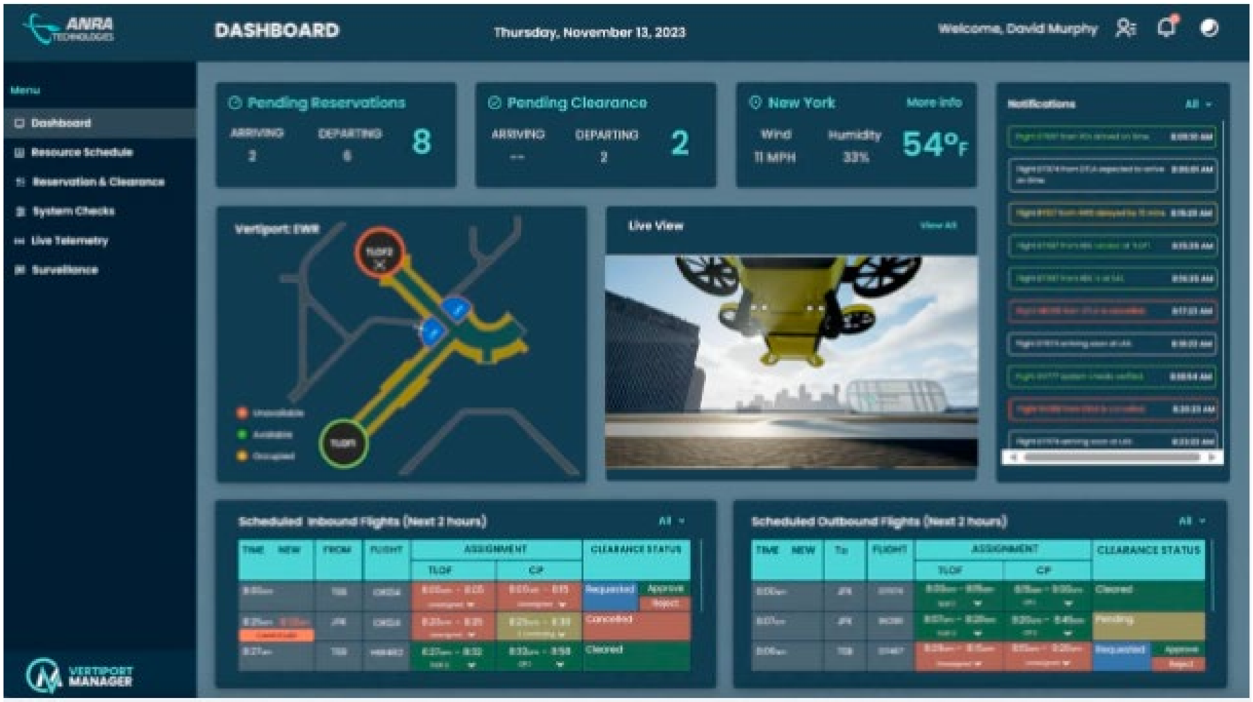


Figure 73:Example of a Vertiport Management System software. Source: ANRA Technologies https://www.anratechnologies.com/home/

16.2.2 Regulatory Considerations for UAM

From a regulatory standpoint, near term approvals for vehicle development and use may be achieved via existing avenues of approval consistent with traditional aircraft, i.e. initial UAM operations are conducted using new aircraft types that have been certified to fly within the current regulatory and operational environment. As operations become more complex, regulatory evolution, including development of UAM Corridors, may be developed along with industry collaborative technologies and procedures.

16.2.3 Economics of AAM

The NEXA Capital report referenced in the Executive Summary projected that AAM could add more than $12 billion to Virginia's GDP over the next two decades and create more than 17,000 jobs. Projections from other independent industry sources contain similar estimates for AAMs economic potential. In October of 2023 California State University, Long Beach published a study titled, "The Economic Impact of Establishing and Expanding Urban Air Mobility Operations across Southern California[60]" which details the financial components involved in establishing an initial vertiport network and expanding to twenty vertiports, including expected initial capital expenditures and the resulting regional impact in terms of job creation and associated benefits.

[60] https://wisk.aero/wp-content/uploads/2023/10/The-Economic-Impact-of-Establishing-and-Expanding-Urban-Air-Mobility-Operations-in-Southern-California-online-version.pdf

Highlights of this study include details on the construction and capital expenditures phase that begins with a six-vertiport system, costing an estimated $82.0 million in outlays that include:

- $37.8 million in construction spending,
- $16.1 million for communications infrastructure expenditures
- $16.0 million for upgrading the electrical grid

The economic impact of the initial 6-vertiport construction phase is expected to be:

- 803 jobs created, including 472 direct jobs and 331 indirect
- $67.5 million in labor income, including $42.4 million in direct income and $25.1 million in indirect
- $153.9 million in output, consisting of $82.0 in direct output and $71.9 million in indirect and induced output.

When the system is expanded to twenty vertiports it is estimated that the total cumulative outlays for the region will be $226 million, resulting in 2,133 jobs, $174.0 million in labor income, and $423.6 million in economic output. These estimated results indicate that every $1 million in direct expenditures results in $1.9 million in total output, and for every $1 million in direct expenditures, 9.4 jobs are created.

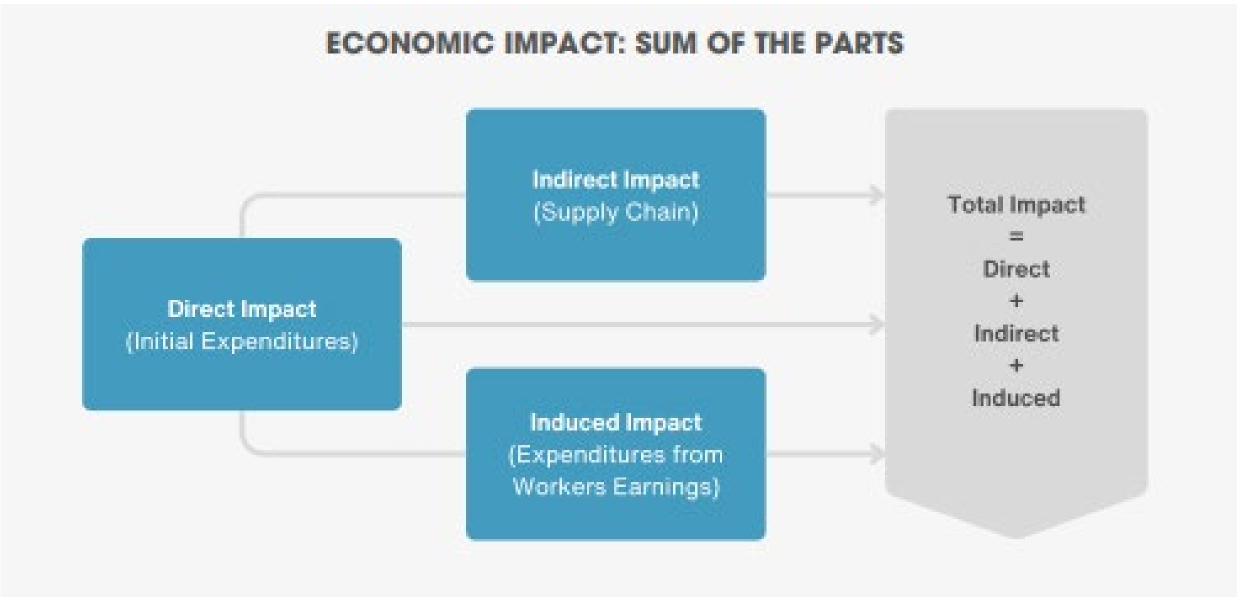


Figure 74:Examples of AAM economic contribution impacts on the economy. Source: California State University, Long Beach. https://wisk.aero/wp-content/uploads/2023/10/The-Economic-Impact-of-Establishing-and-Expanding-Urban-Air-Mobility-Operations-in-Southern-California-online-version.pdf

17.0 Recommend Next Steps

17.1 Small Uncrewed Systems

Investing strategically in a careful mix of projects can yield meaningful benefits in the short term and position the state competitively to become a hub for this industry as it develops. The following recommendations for state investments consider costs, efficiency gains that foster economic viability, safety, and prioritizing investments in technologies with a clear path to regulatory approval.

- Establish detect and avoid services at strategically selected existing test sites using proven ground-based systems.
- Preferentially establish pilot programs in areas protected by mandated ADS-B equipage.
- Enable pilot programs for smaller-scale operations by utilizing cost-effective radar and acoustic detection systems, which have medium functional ranges but are efficient when networked.
- Identify and establish public-private partnerships with manufacturers of small UAS to support pilot programs, and with companies focused on larger vehicles to support the equipage of advanced testbeds.

17.1.1 Establish detect and avoid services at existing test sites

While meaningful progress can be made in integrating AAM applications over the next five to ten years, the numerous challenges in fully certifying autonomous systems, including large passenger-carrying systems, and guaranteeing an adequate level of safety extend the timeline for full implementation decades into the future. This creates a lengthy period when OEMs will require well-equipped test and validation ranges, and when state investments in those ranges will pay dividends.

In the near term, a primary barrier to progress in integrating autonomous aircraft is the absence of regulations that permit routine flights beyond the pilot's visual line of sight. Flights covering longer distances are mandatory for most applications to be economically viable, conducting them safely demands a technological alternative to the crewed pilot's ability to see and avoid other aircraft.

To detect noncooperative aircraft, sUAS will be reliant on ground-based detect and avoid capabilities. As described earlier in the report, there are numerous candidate technologies for this purpose. These systems are in various stages of maturity, and many will require validation against a proven solution. A mid-range radar with validated performance characteristics can both support operational testing of sUAS ConOps and test and validation of other detect and avoid technologies.

A validated system can also support testing of the onboard detect and avoid systems that will be utilized by larger AAM aircraft. While these will mostly be optionally piloted in the near term, progression towards full autonomy will require validation of these onboard solutions. Additionally, these onboard systems experience significant ground clutter when descending into a terminal environment; NASA and FAA ConOps suggest that these passenger carrying systems will transition from cruise flight corridors to vertiports through an umbrella of ground-based detection systems to counter those effects. All these considerations mean that investing in high-performance ground-based systems will enable testing and validation for near-, mid-, and long-term applications.

Virginia boasts an impressive mix of test ranges in diverse environments with numerous advantageous characteristics. Supplementing the resources already available in these environments with proven detect and avoid systems will attract AAM companies seeking well-equipped test and validation environments.

We suggest the following approach to equipping test ranges that will be attractive to OEMs and other potential partners:

1) Identify existing test sites that have a strong set of authorizations and resources, preferably in sparsely populated areas with sufficiently low ground risk to permit advanced testing. Proximity to one or more airports is also desirable, to support research on terminal approaches.
2) Supplement resources at those test sites with long range communications and detect and avoid systems (e.g. radars) to support validation of on-board detection systems for larger AAM aircraft.
3) Encourage public private partnerships with AAM OEMs to locate their testing at these sites.

17.1.2 Establish pilot programs in areas protected by ADS-B mandated equipage

Operations in airspace where ADS-B out is required for crewed aircraft can expedite approvals for more advanced operations by reducing the obligation to detect noncooperative aircraft. ADS-B has been demonstrated to be a highly effective method for meeting separation distances specified in ASTM safety standards, and ADS-B detectors are relatively low-cost. Deploying these sensors in ADS-B mandated areas is a cost-effective way to facilitate approvals and ensure safe operations.

The four ADS-B mandated regions coincide with metropolitan areas. That makes these regions most appropriate for Use Case 1 (drone as first responders in densely populated areas) and 4 (commercial delivery in large suburban areas), whose value proposition is higher in urban areas.

It should be noted that this approach is not yet fully supported by regulation, largely because of certain exceptions to equipage requirements (such as military aircraft or those without electrical generators). However, there are strong indications that this approach is gaining traction and we expect to see approvals of this type in the near future. Notably, the BVLOS Aviation Rulemaking Committee recommended utilizing ADS-B for detect and avoid for all operations below 500’ – not just those in areas where ADS-B is mandated today. The traditional aviation sector has pushed back on this recommendation; however, it is likely that some form of this rule will be proposed and eventually enacted. The relevant notice of proposed rulemaking is expected to be released in the summer of 2024 with an effective rule a year later. This points to the likely large-scale acceptance in rulemaking and practice of leveraging ADS-B as the sole detect and avoid tool in areas where it is required as a method for crewed aircraft conspicuity.

Even prior to rulemaking, this equipment represents a sound investment in ADS-B mandate areas, because the cost of enabling BVLOS operations is dramatically reduced when noncooperative detect and avoid is not required.

We propose the following recommendations:

1) Work with industry to identify areas covered by the ADS-B mandate that will offer economic benefit; provide infrastructure in the form of ADS-B receivers, internet or LTE services, constraint and traffic management services (UTM) to support operations such as Use Case 4 (commercial delivery in large suburban areas).
2) Work with municipalities to identify areas covered by the ADS-B mandate that will provide efficiencies for first responders; provide infrastructure in the form of ADS-B receivers, internet or LTE services, constraint and traffic management services (UTM) to support operations such as Use Case 1 (drone as a first responder in in large suburban areas).
3) Develop and implement a plan for community engagement that encourages acceptance of these services (Section 14).

17.1.3 Establish pilot programs for smaller scale, cost effective operations

In order to adequately support Uses Cases 2 (rural and remote medical delivery) and 3 (on demand emergency support) the state should develop small-scale pilot programs that can serve as the foundation for regulatory approvals. These pilot programs will become the model by which other operations across the state can be rolled out.

Mutually beneficial partnerships involving public agencies, champion operators, and service providers will play a key role in enabling these operations by distributing costs while extending beneficial impacts.

Technologies that should receive early consideration for supporting these pilot programs include constraint and traffic services (UTM) combined with smaller-scale, lower-cost detect and avoid systems such as acoustic and medium range radar. The deployment of these systems in a network will ensure an adequate level of safety through redundancy and will allow operations to scale smoothly from shorter to longer-range operations.

We propose the following recommendations:

1) Identify rural areas within the state for establishing a pilot program for Use Case 2 (medical deliveries in remote rural communities) and Use Case 3 (on demand emergency response, *fixed* asset).
2) Partner with champion operators and constraint, traffic management and supplemental service (remote ID and weather) providers to establish a pilot program in those rural areas identified above; support with acoustic and medium range radar detect and avoid systems, to support Use Case 2 and 3 (fixed assets).
3) Utilize the pilot programs for Use Case 2 and 3 (*fixed*) as a validator of concepts to support a subsequent pilot program for Use Case 3 (*mobile*).
4) Partner with champion operators and constraint, traffic management and supplemental service providers (remote ID and weather) to establish the pilot program for Use Case 3 with a mobile operations center and mobile assets, again utilizing acoustic and medium range radar detect and avoid systems.

5) Develop a plan for community engagement that encourages acceptance of services (Section 14).

17.1.4 Establishing Public - Private Partnerships

A prerequisite for beginning implementation of the Commonwealth AAM infrastructure development projects is identifying appropriate public-private partnerships. Success stories stemming from these partnerships can be found in North Dakota, North Carolina and New York. Virginia should adopt a similar approach in establishing infrastructure for small UAS operations and making investments to attract larger aircraft OEMs.

Some infrastructure needs covered under this program would include hardware and software for the creation of a backhaul data network and standardized end-user infrastructure access. Technology providers should be sought as partners in developing the underlying components for MVI development, particularly the backhaul data network, system access and monitoring, and sensor integration efforts. This approach would provide the Commonwealth with a foundation on which to build out the additional "as needed" MVI components. As proposals are received and approved, their individual solutions may be integrated with the network to access shared resources.

A public/private cost sharing effort for individual use cases would also contribute to hardware, software, and test and evaluation efforts for a mutually beneficial use case between a private entity and the Commonwealth. Technology and software providers have a vested interest in seeing their products gain regulatory approval and early adoption, and as such may be primed to form strategic partnerships for AAM infrastructure emplacement where state assets are applied to achieve the same goals. These partnerships will likely come from seeking out champion operators willing to utilize the technology for use cases of common interest, and jointly submit for approval for inclusion in the Commonwealth AAM infrastructure network.

The state should engage with AAM stakeholders to identify strategic locations that may benefit from adding infrastructure to support early test and validation activities for OEMs. This could be done by leveraging the existing capabilities and facilities of Virginia's Test Sites.

These partnerships and early use cases will set the groundwork for approval at both the State and Federal level for follow-on use cases that have similar needs and solutions sets, and set precedent for repeatable and cost effective AAM operations.

We propose the following recommendations:

1) Establish a funding program where private companies focused on supporting small UAS Use Cases 1-4 can propose to partner with the state on establishing necessary infrastructure (backhaul data networks, detect and avoid technologies (where applicable), constraint and supplemental data services (remote ID and weather) provided as a service through a USS).
2) Establish a sister funding program for private AAM aircraft OEMs to partner with the state on building vertiports at Test Site locations where the state has provided a detect and avoid umbrella (see recommendations and next steps on establishing technologies at a few Test Sites).

17.2 AAM/UAM

With the FAA ConOps 2.0 and early UAM Maturity Level plans under the NASA UAM Airspace Research Roadmap suggesting the use of current airspace infrastructure with optionally piloted aircraft for the near term, we recommend the state focus on the few areas in which it can make investments that will provide relatively earlier benefit and also serve as a foundation for future investments.

17.2.1 Invest In and Develop Vertiports and Instrument Approaches at Test Sites

Virginia Tech conducted interviews with multiple aircraft OEMs and found a common consistent need mentioned regarding the development of vertiports and instrument approaches at areas where aircraft operations can be proven out for transitions from takeoff to the current airspace infrastructure and then to landings. Strengths mentioned around the development of this infrastructure generally include the following benefits:

1) Provide OEMs with an array of vertiports and vertistops for demonstrating capabilities in conducting flights between locations.
2) Opportunities to perform research that provides the regulator with real world examples of optionally piloted transitioning from the existing enroute instrument digital infrastructure (RNAV routes) to instrument infrastructure developed in conjunction with vertiports.
3) Provide aircraft OEMs with a place to demonstrate capabilities in an area that is close to the regulator (Virginia specific strength)

17.2.2 Develop vertiports and instrument procedures accompanying those vertiports in a few areas that will prove beneficial for early cargo operations.

Early certification of aircraft and public acceptance of the use of AAM aircraft will most likely start with aircraft conducting cargo operations. Investing in a few vertiports and instrument approach procedures (for separation services, sequencing and to accommodate efficiency requirements of EVTOL/SVTOL aircraft) at locations that will be optimal economically for the movement of these goods (see Section 16) and will serve as to encourage the use of this infrastructure for operations. Careful planning should be considered that develops this infrastructure at places where cargo companies conducting Part 135 operations have the support of local municipalities and room to develop warehouse facilities nearby.

17.2.3 Additional Efforts to Attract AAM Industry to the Commonwealth

To encourage growth in UAM/AAM within the state, Virginia could offer incentives similar to other states. Like the Genius NY competition mentioned in Section 3.2.1, states like California are offering AAM companies' significant incentive to locate operations in their state. These incentives are strategic efforts that create workforce training and related jobs, while also paying huge dividends in state economic benefits.

The California Competes Tax Credit[61] is an income tax credit available to businesses that want to either move to or remain in California. Application periods are open at fixed times throughout the year for businesses to compete for over $180 million in available tax credits. Applicants are

[61] https://business.ca.gov/california-competes-tax-credit/

analyzed across various factors, including job creation, economic investment, and strategic importance to the state or specific region.

In November of 2023, two AAM companies each received substantial grants from the program. AIBOT specializes in AI-defined eVTOL aircraft and has been awarded a $15 million grant through the program for continued development, flight testing, and manufacturing capabilities. It is estimated that AIRBOT will create almost 700 new jobs in the state and invest close to $500 million in capital over the next 5 years[62].

Joby, another eVTOL aircraft developer, has been awarded a $9.8 million grant through the program to assist them in expanding their manufacturing and pilot and maintenance training facilities. It is estimated that Joby will create almost 700 new jobs and invest over $40 million in California over the next 5 years[63].

Texas formed an Advisory Committee led by the Texas DOT that drafted a report on Urban Air Mobility to make recommendations. Those recommendations included creating a "sandbox" to encourage OEM's to come and test within the state at these locations[64].

These types of financial incentives, combined with well-developed test and research facilities and related infrastructure such as a robust and secure digital infrastructure, and on and off-airport public use vertiports and vertiport networks, will create a 'sandbox' for industry to test technology and understand interoperability with digital infrastructure. Combined with close proximity to FAA and NASA facilities and geographic diversity from coast to mountains that supports a wide variety of use cases, Virginia could position itself to be an AAM industry destination.

sUAS use cases and related infrastructure were suggested as near-term focus areas for setting the ground work for larger AAM implementation across the Commonwealth. Section 16 outlines two larger AAM use cases that should be considered for a follow-on study that would look at how state infrastructure support could be provided once the regulatory pathways for certification of aircraft and operations are more clearly defined.

18.0 Appendix

Appendix A – Community Engagement: Best Practices for Drone Operators

Appendix B – Perspectives on Drone Delivery

[62] https://www.urbanairmobilitynews.com/air-taxis/aibot-receives-usd15-million-calcompetes-grant-boosting-evtol-industry-and-job-creation-in-california/
[63] https://verticalmag.com/press-releases/joby-receives-calcompetes-grant-to-support-california-facility-expansion-and-690-new-jobs/
[64] https://ftp.txdot.gov/pub/txdot/avn/final-report-advisory-committee.pdf

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Appendix A

Community Engagement: Best Practices for Drone Operators

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Wing

Community Engagement: Best Practices for Drone Operators

The Wing-MAAP team's guide to working with communities

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INTRODUCTION

This document contains information and background that Wing and Virginia Tech's Mid-Atlantic Aviation Partnership (MAAP) have found to be helpful in engaging with a community prior to and during operation of a drone package delivery service. The information has been collected through engagement during multiple launches of Wing's delivery service - in Australia, Finland and the United States - and ranges from providing briefings to high-level public officials to direct conversations with community members at public events. It does not include discussion of engagement through media or social media, but is instead focused on our attempts to engage directly with community members in person.

With most new and emerging technologies, adoption depends on customers and communities seeing the value of the new service provided and embracing rather than resisting new ways to receive products. Wing and MAAP recognize that the only way for a drone platform to be successful is to provide a service that customers find useful, and that the larger community deems acceptable. Without community acceptance, the service simply won't work. To that end, Wing and MAAP make it a priority to engage with and assimilate into a community prior to introducing our drone delivery service. And whenever possible, we act on community feedback to adopt changes and improvements to our service.

Humility is an essential quality when launching a drone delivery service in a new market. Each community has its own needs and sensitivities; its own history and way of life. While we may know our technology better than anyone else, community members know best the kind of service they require. Approaching community engagement with an understanding that the community itself has some of the answers to a successful drone operation is an important principle.

It is also important to note that different applications of drone technology involve different levels of engagement with members of a community. A package delivery service like what Wing provides is inherently a high-visibility application that involves a great deal of direct interaction with customers as well as non-customers. For that reason, Wing and MAAP used an intensive, high-touch approach of engaging community members prior to launching the service. Other drone applications may involve less interaction with community members, and therefore each and every element of the strategy discussed below may not apply.

OVERALL STRATEGY

For our community engagement efforts, Wing and MAAP incorporated three overarching principles in our approach: educate, listen and respond. These three components support an outreach strategy that furthers our broader goal of launching a service that best meets the community's needs and minimizes impacts that may be perceived as negative.

A Note About COVID-19:

As noted throughout this document, a key to effective outreach is to have direct, in-person conversations with community members to convey information and elicit feedback. During the COVID-19 pandemic, those opportunities are extremely limited or simply not available at all. Instead, Wing and MAAP have pursued engagement opportunities online and in the form of virtual meetings. Phone calls and video conference presentations to local groups and organizations have taken the place of booths at festivals and in-person meetings. These events still allow Wing and MAAP to continue conversations with community members and highlight new developments with the drone delivery service, which is particularly relevant given the surge in demand for our services during the pandemic. Having already established strong community connections through outreach efforts prior to launching service, Wing and MAAP were able to draw from those relationships to understand and respond effectively to the community's changing needs. Additional strategies include highlighting service updates through local media channels and supporting local fundraising efforts for frontline workers during the pandemic.

Educate

Perhaps the most important component of gaining community acceptance is educating community members on what your particular drone platform is, as well as what it is not. Community members may approach the concept of drone operations with certain preconceptions, some of which may be negative, and apply those thoughts to any and all drone operations without recognizing that drone platforms vary widely in how they operate and for which applications they are used.

At Wing, as with many other drone companies, an enormous amount of effort went into customizing our drone service and package delivery system to meet particular performance requirements while sacrificing other capabilities that are not essential to our operations and, in some cases, could engender public concerns (e.g. we do not employ a camera with images viewable by the pilot). As part of that process, we have also worked to address key concerns that we hear frequently about UAS technology.

When speaking with community members, concerns are generally raised around recurring themes; particularly safety, privacy and noise. Those concerns could be developed through personal experience, but are often based on news reports or general background about drones that don't necessarily apply to all of the various different platforms that now exist.

Being present in a community before your drone service has begun provides the opportunity to educate community members about how your service operates, what benefits it provides and how you plan to establish appropriate channels for continued community interaction. It also allows you to hear about particular concerns, explain how you have addressed or plan to address those concerns, and to clear up any misconceptions about how your particular drone platform operates.

For example, many people share concerns about drones taking video footage of their homes or activities. When we have community events, we explain that Wing drones have a downward-facing, low resolution, grayscale camera that is used for navigational purposes. Community members who have expressed concerns appreciate the information about Wing and our operations.

Bringing an understanding to the general public of the benefits of drone services, while noting the ways in which recurring concerns have been taken into account, can be one of the most challenging yet effective efforts in developing public acceptance.

Listen

Direct in-person presence allows for dialogue: helping the drone operator get crucial feedback from potential customers while allowing people to share their thoughts and concerns in a way that reassures them they are being heard by the drone operator. These interactions can also provide key insight for the drone operator on how to make meaningful improvements to its service.

It can be helpful in both the short- and long-term to develop a system to collect data on public sentiment that will allow you to track general trends and reactions (detailed below in the "Capturing Public Sentiment" section). Conversations at a community festival booth can sometimes be brief, but providing contact information so that individuals can follow up with real people has proven to be helpful in continuing those conversations and building relationships.

Listening to the views of community members and extending these conversations means community members feel they are being heard and are part of the process of developing a new service. Because sentiment towards drone delivery and drone operations in general will vary widely in a diverse community, it will likely be impossible to address or resolve every individual's potential concerns. However, providing an avenue for community members to directly voice their opinions can be constructive and contribute to the success of a drone service in the community.

For larger operations, listening to community members also involves conveying relevant input to the appropriate department or team. To ensure the experience is effective from a community member's perspective, that means that the staff member taking feedback must see that feedback is delivered to the appropriate staff who can address it. Failure to follow up on a question raised by a community member, particularly if part of a broader trend, can spoil the outreach efforts and poison the well for your company's longer-term relationship with that community.

Respond

An important component to listening involves the ability to respond to whatever feedback is provided. First, consistency in responses provided is important so developing a common script that all team members can work from ensures that community members are receiving the consistent responses to common questions. Team members working at outreach events could come from varied backgrounds or have varied levels of expertise, so working from a standardized set of responses to commonly asked questions will help to avoid any confusion for community members who could otherwise come away from an interaction having received discordant or conflicting information.

When well-founded complaints or concerns are voiced, it is important to respond with concrete action in an attempt to resolve the issue. In the case of Wing's engagement, much of the feedback has involved the provision of service itself: Can we provide service to an address or neighborhood? Can we provide additional services - deliveries over a longer time period or provide additional items for delivery?

In many ways, this can be viewed as positive feedback, as it shows that community members and customers enjoy the current service and would like to see it expanded. When possible and when it makes sense from the perspective of growing the service long-term, Wing attempts to accommodate these requests. For example, we have expanded our merchant offerings on the app in Australia to include additional merchants who offer a much larger selection of goods for delivery to our customers and we continue to explore ways to expand our delivery area.

Other feedback could involve complaints about a drone operation: when and where the operation takes place, proximity to certain areas or homes, the noise or other disturbance associated with operations, etc. As an example, in its early operations Wing received feedback related to the noise emitted by our drone operations. In response, Wing addressed those concerns by taking measures such as redesigning our hover propellers to reduce both the volume and pitch of noise generated by our drones. Another example is that Wing has designed its route planning software to randomize routes in a way that distinct "drone highways" or specific routes are not taken for each and every flight in an effort to minimize repeatedly flying over any given land parcel when making deliveries. In addition, locating the base of operations in a commercial district rather than in close proximity to quiet residential areas can ensure that the highest concentration of flight activity is localized in a part of town already busy with commercial activity.

Being able to demonstrate that a drone operator can and will take action to address community concerns is effective when talking to community members to show that drone industry participants value the feedback they receive and take concrete actions to do something about it. Not every concern can be addressed with a direct solution, but experience has shown that community members value efforts taken to listen and address issues raised within the communities being served.

STATE & LOCAL GOVERNMENT

Well in advance of the date scheduled for operations to begin, a drone operator may want to set up meetings with the relevant state and local government officials, as well as other important stakeholders who are known within the community. Local government officials include the Mayor and City Manager, members of the Town or City Council, County Board of Supervisors and key staff, local economic development officials and others that may be identified as being important.

State officials would include key members of the governor's team and cabinet, department of aviation officials, local members of the state General Assembly as well as their staff.

It is important to conduct these meetings early in the process of beginning a drone operation for several reasons:

» To ensure that local decision-makers are equipped with early knowledge of the situation so they can be an informed voice with their constituents.
» To get to key stakeholders early so that they are hearing accurate information directly from the drone operator rather than potential misinformation from other sources that would require effort.
» To provide an opportunity to begin two-way conversations and build relationships with stakeholders, allowing ample time for them to approach us after an initial meeting with further questions and to provide us time to follow up with responses on any concerns.

Holding these conversations early allows ample time for the outcome of these meetings to inform future outreach, so that insights gleaned from stakeholders can help the company tailor their outreach approach and their service more effectively to the specific needs and priorities of the community.

The purpose of these initial meetings is to introduce your company to local officials, describe to them your plans and goals, expand on the benefits of your services, provide the officials with an opportunity to ask questions or express concerns, and to solicit advice from local officials on other important stakeholders to talk to and any particular actions that should be taken in becoming a member of the community. Perhaps most importantly, these meetings help with forging important relationships with key stakeholders in a friendly, introductory environment.

This initial set of meetings with local elected and state officials can be followed by additional meetings with important stakeholders in the community, which can include potential supporters who can speak positively of your presence to other community members as well as potential groups who may be cautious about embracing drone delivery services.

ADDITIONAL STAKEHOLDERS/PARTNERS

Stakeholders include the local chamber of commerce, leaders at local educational institutions, leading voices in various different local communities or groups (e.g. particular cultural associations, active technology/robotics or environmental groups, local AARP chapter, etc.). Given that drone technology must safely share the skies with other types of aircraft, it is also important to have your company's drone pilots and technical experts meet with members of the local aviation community to explain your concept of operations and provide lines of communication to ensure any and all questions can be answered.

Experience has shown that conducting these meetings with a respected local partner, if possible, can be very effective in allaying concerns and driving support. As an example, in launching its Virginia operations, Wing's partnership with MAAP, a division within Virginia Tech, carried with it the valuable affiliation with the university. Including representatives from MAAP in meetings reinforced with the local community that Wing had the support of a trusted local partner.

IDENTIFYING OUTREACH OPPORTUNITIES

Every community presents opportunities for a drone company to engage with community members simply through participating in the large-scale, public events that are hosted within a community each year. These can range from farmers' markets to street fairs, health & wellness events to music or food festivals. Some events won't be appropriate for engaging in discussions about providing drone services. However, events that attract a good cross-section of the community and that allow you to rent out or set up a booth can provide a great opportunity to engage with the community. Something as simple as scanning community event calendars can be helpful in identifying good options. If you are unfamiliar with a community, local elected officials or other community leaders are often happy to suggest good options.

It can be worthwhile to think creatively about outreach opportunities. Consider securing a presence at events that may not traditionally be associated with a new and emerging technology like drone operations. As an example, Wing and MAAP have had success by identifying outreach opportunities such as home shows, aging conferences and AARP chapter meetings to start conversations with community members about the benefits of drone package delivery. Thinking about drone operations as a way of improving people's everyday lives rather than just an exciting new technology can change people's perspectives and helps to re-frame the way that a community views the role of drone operations. This perspective can also be helpful in identifying outreach events and framing your message as you engage with community members at those events.

CAPTURING PUBLIC SENTIMENT

While engaging with a community about your company's drone operations, it is important to be able to track the extent and nature of the feedback provided. Being able to quantify the number of community members that you spoke to can be important information for federal regulators, local leadership and internal discussions that can shape the future direction of the company. In addition, capturing information about whether community members feel positively or negatively towards your operations and what specific factors weigh into those feelings can be extremely important in analyzing your success in a market and gauging how to grow and adapt.

In a common situation, a drone company team member will find herself staffing a booth at a community festival or other public place and engaging in one-on-one (or group) conversations with community members in somewhat crowded environments. Those situations are not always conducive to taking timely and specific notes about particular questions or concerns that a community member may voice. To address that challenge, one possible solution is to incorporate a system of tracking public sentiment by using tablets during events and minimizing the amount of work an employee would have to do at the event to provide an accurate sense of a community member's feedback. Using a document with predetermined categories that generally describe the nature of positive or negative sentiments can quickly provide information about the number of people sharing feedback, and what specific type of concern it is. Staff can also take notes after the interaction if more specificity is needed. For particularly crowded and chaotic events, it can be effective to designate one person on staff to focus on collecting feedback with the tablet rather than engaging in conversations with community members.

Feedback collected at community events is valuable to ascertain information about broader trends. By having direct contacts with thousands of community members, it allows you to get a good cross section of community views about your service. In the case of the Wing-MAAP team, for example, these direct, organic conversations inform us about how a particular community values the convenience, product offerings or environmental benefits of our service, and allow us to hear questions or concerns. In addition, collecting feedback through the use of a document with predetermined categories allows for collection of standardized data across multiple markets with the ability to run comparative analysis between those markets.

During community outreach events, there is the potential for uncomfortable or tense conversations with members of the public who may disagree with the service or have more general concerns about new technology. This could involve someone using offensive or derogatory language, acting physically aggressive, or using a cell phone to record an awkward exchange. In Wing's experience having hosted over 100 information booths across three countries, uncomfortable situations have been extremely limited and relatively mild in nature. Nonetheless, it is important to remain prepared in case a situation arises.

If such a situation arises, it is advisable to use conflict resolution practices such as maintaining eye contact, actively listening, and keeping a friendly rapport while also making a note of any action items. Actions items could include tracking down follow up information that a team member doesn't have at the ready in order to share with the community member at a later date. For public events, always consider security arrangements, including taking note of any law enforcement presence. Consider adopting a policy of requiring at least two team members present in order to avoid leaving one employee to handle a situation by him or herself. Developing and talking through an action plan beforehand is also important so that team members are confident in what steps to take if such a situation arises.

GUIDELINES FOR COMMUNITY OUTREACH EVENTS

Apart from participating in broader community festivals or events, your drone operation's outreach events will often fall into two categories: a community stall/booth, or a community demonstration. At Wing, stalls/booths will involve a table where staff can display the drone, a representative package used in our deliveries, and accompanying materials that help demonstrate how the technology works. We have found that simply having the drone itself on display is very effective in attracting the attention of community members. It is also a good way of introducing people, particularly children, to the aircraft in a way that is not intimidating and allows them to examine the components up close.

Flight demonstrations can be even more effective in allowing community members to see how the technology actually works. Staff can identify suitable plots of land in a community that can host members of the public while also being able to provide for a safe demonstration of the drone technology. During a flight demonstration event, it is advisable to space out the flights so that community members can filter in and out of the event and still witness how the system works. At flight demonstrations, staff should also have a stall or booth to help with providing informational materials, answering questions, and helping people sign up to use the service.

OUTREACH EXPERIENCE FOR THE WING-MAAP TEAM IN VIRGINIA

Wing began its drone delivery operations in Christiansburg, Virginia in October, 2019 in partnership with Virginia Tech's MAAP and the Virginia Center for Innovative Technology under the U.S. Department of Transportation's Integration Pilot Program. Leading up to the launch of service, Wing and MAAP jointly executed a comprehensive community outreach strategy that closely followed the principles laid out above.

Targeted Outreach with Government Officials and Local Stakeholders

In the summer and early fall of 2019, Wing and MAAP scheduled meetings with Town Council members for the Town of Christiansburg, members of the Montgomery County Board of Supervisors, the Governor's office, and federal and state legislators who represent the region. In these meetings, we briefed officials on the background of Wing, our plans for operations in Christiansburg and our strategy to engage local community members about the upcoming service. In each meeting, we also solicited feedback from the officials in an effort to gauge their level of support, understand any advice they had for us to maximize our success, and learn of additional stakeholders in the community we should meet with directly. These initial meetings also served as friendly introductions to lay the groundwork for constructive longer-term relationships going forward.

In addition to elected leaders, the Wing-MAAP team also met with prominent local stakeholders and members of key groups. These groups ranged from the local chamber of commerce to law enforcement and first responders, including the local police and fire departments as well as the county sheriff.

Wing and MAAP team members with Christiansburg Mayor Michael Barber

We also scheduled meetings with key aviation stakeholders to ensure coordination with other groups who would be using shared or neighboring airspace. These groups included the manager of the local airport, leaders in the local medivac and helicopter community as well as members of the local drone hobbyist community. We were careful to include our pilots and technical staff in these meetings in order to engage in discussions that could delve into specific and technical aviation issues.

Presence at Widely-Attended Community Events

Wing and MAAP worked to identify community festivals in the region that would be suitable for securing a Wing-MAAP booth where we could provide flyers and background materials to distribute, display a drone and our delivery mechanism to demonstrate our technology in-person, and have staff on hand to explain our plans and answer questions.

MAAP and Wing team members at Christiansburg's Touch-A-Truck festival

The events ranged from the largest regional street festival to much smaller and more intimate gatherings that attracted more modest foot traffic. As an example, Wing and MAAP team members staffed a booth at Steppin' Out Blacksburg, a two day festival that generally attracts roughly 40,000 attendees. Other events included the Kiwanis Wilderness Festival, the Christiansburg Food Truck Rodeo, and multiple appearances at the local farmers market and a kiosk in the indoor mall.

Attending these events allowed Wing and MAAP to interact with a large number of community members, educating them about our drone delivery service while also getting important feedback from potential customers. Having a presence at a range of different events also allowed us to build awareness with a wide variety of community members from different neighborhoods and income brackets.

Importantly, Wing and MAAP continued to have a presence at community events and local gathering places after the initial launch of our delivery service. This continued presence helped demonstrate a commitment to the community and allowed community members to continue dialogue with us. Discussions changed over time as well, with initial conversations focused on educating the public about who we are and what we do and later conversations focused on troubleshooting how people can sign up for the service and taking suggestions for how the service could be improved.

The Wing-MAAP team has also found ways to expand our outreach once the delivery service was up and running. We have invited several groups of community members, including entire classes of middle and high school students, to Wing's base of operations in Christiansburg to provide background on the drone delivery operation and educate more generally on drone technology and safe operation. The Wing-MAAP team has found these opportunities to be very well received by student groups and an effective tool to help generate enthusiasm among local students to pursue careers in the field.

Tour of Wing's Christiansburg operation

Hosting Information Sessions and Flight Demonstrations

Wing and MAAP hosted multiple events that allowed for community members to witness the drone delivery system in person prior to Wing's service officially beginning.

Wing organized a widely-attended gathering, held at a large centrally-located outdoor space. Wing sent invitations by mail to a large majority of the residences within the delivery footprint, inviting community members and local leaders to attend a picnic event on a Saturday afternoon. At the event, Wing, MAAP and other partners each had booths staffed by employees to provide information and materials with details about how the service would work. Most importantly, over the course of the event Wing made drone deliveries to the event every 15 minutes to allow attendees to witness how the technology works up close. Exhibiting the delivery system in person prompted constructive questions from attendees and potential customers. It also served to build a comfort level in, as well as excitement about, the upcoming service that we would offer.

In addition to the picnic-style event, Wing and MAAP hosted smaller scale demonstrations at other venues around town. These events were announced beforehand on local media and, although they did not include the enticement of free food, also provided the opportunity for attendees to witness deliveries firsthand. At each event, Wing and MAAP had staff and background materials on hand to provide helpful information and answer questions between deliveries.

Hosting multiple flight demonstration events provided different opportunities for community members to view the delivery system prior to launch in case one particular date wasn't suitable for everyone. Varied venues around town helped us expose a cross section of the community to the service. We have found that witnessing the experience in person was an extremely effective tool in educating the community about drone delivery and helped create local excitement about its benefits.

Taken as a whole, Wing and MAAP found the strategy described above to be successful in creating an overwhelmingly positive community response to the drone delivery service. Engaging early and establishing constructive relationships with leaders and community members helped pave the way for a successful launch of the delivery service and began a constructive dialogue with the community from which we continue to benefit as we work to modify and improve the service.

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Appendix B

Perspectives on Drone Delivery

Perspectives on drone delivery

From the first community in the U.S. to experience residential package delivery by drone

Executive summary

Public attitudes towards drone delivery will significantly influence the ultimate success of these programs in communities. Data on this topic is limited, however, and no study has evaluated how drone delivery is perceived in a community that has had first-hand experience with it. Researchers from Virginia Tech conducted such a survey in Christiansburg, Virginia (Va). Christiansburg is the site of the first service in the U.S. to deliver goods directly to residences on demand via drone, launched by drone-delivery company Wing in October 2019. Survey respondents (n = 821) answered demographic and psychographic questions and provided quantitative feedback on drone delivery including general sentiment, familiarity, and likelihood of use, and qualitative feedback on its perceived positive and negative attributes. In contrast to previous surveys, this study found a strongly positive attitude towards drone delivery, with 87% of respondents reporting positive sentiments and 89% stating that they were likely to use the service if it were available; 87% of respondents reported that they viewed the use of drones for package delivery on equal or more favorable terms than other uses of drones. These results suggest that communities may be significantly more receptive to drone delivery than earlier studies have suggested and have implications for policy and outreach on this topic, as well as for survey methodology.

Background

Over the last two years, several companies have earned permission from the FAA to deliver packages by drone. Small-scale trial services, usually with tight restrictions, are operating in a handful of communities around the country; maturing technology and regulatory shifts suggest that drone package delivery could become more commonplace over the next decade. Among potential commercial applications for drones (also known as UAS, or unmanned aircraft systems), package delivery is notable for its direct interaction with consumers and high degree of visibility in the community. Therefore, public receptiveness to this technology is highly salient to the regulatory agencies developing rules that will govern its use, companies evaluating new markets, and state and local governments considering whether to encourage drone delivery in their regions.

However, to date, these groups lack reliable gauges of public sentiment on which to base their decisions. The small number of previous studies of public opinion about UAS delivery have been marked by two flaws: first, they survey individuals who have no direct experience with drone delivery, and are therefore speculating about what such a service would be like. Second, most ask respondents about specific potential risks of the technology selected by the researchers in advance. Explicitly identifying possible risks may have framing effects, leading respondents to focus on hazards and arrive at a more negative overall sentiment than they would otherwise.

For these reasons, Virginia Tech conducted a public sentiment study in Christiansburg, Va., where the population has experienced UAS delivery for more than a year. In October 2019, Wing launched a drone-delivery trial in the town, a community of 22,163 people in the state's New River Valley region that sits next to Blacksburg, Va (home of Virginia Tech), and 35 miles from Roanoke, Va., the nearest metropolitan region. This was the first service in the U.S. to deliver goods on-demand directly to residences via drone; it was also, and continues to be, the most sophisticated and robust program of its kind.

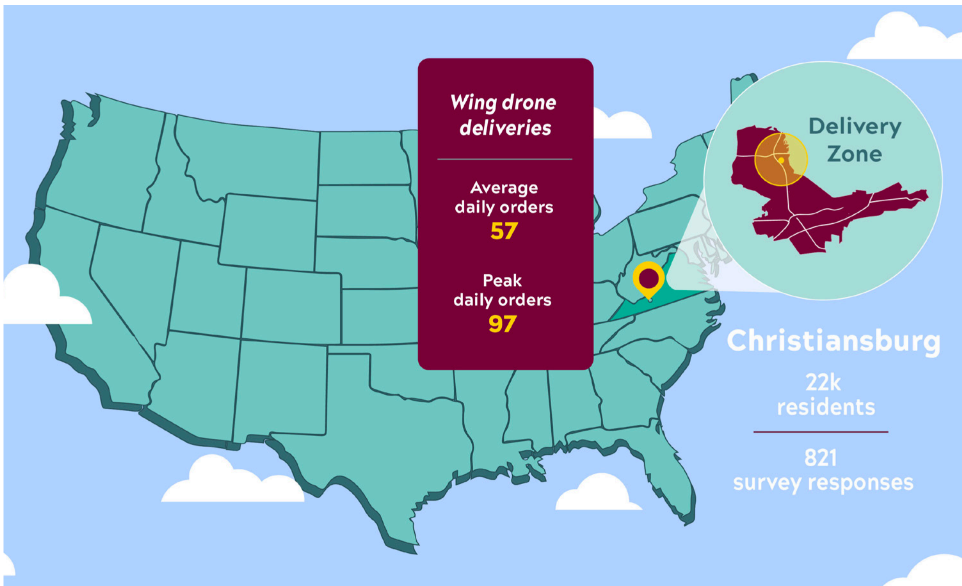

Figure 1. Christiansburg, a small town in southwest Virginia, has had an active drone delivery program since 2019. It is the first community in the U.S. where drones delivered goods to residences on demand, and therefore provides a unique opportunity to study public sentiment towards drone delivery in a community with direct experience with it.

Wing's deliveries originate at a central operations site (a "Nest") located in an industrial-commercial section of Christiansburg that serves several neighborhoods within a three-mile radius. This model much more closely resembles the likely future of drone delivery than any other ongoing programs, which typically have strict limits: operating between two fixed points, for example, or between different facilities within a single medical campus. The vast majority of Wing's flights occur directly over buildings and homes in residential areas, with deliveries primarily to customers in quiet suburban neighborhoods, who must be home to receive deliveries. Wing operates five days per week, with occasional interruptions for weather, holidays, or other factors. Daily order volumes fluctuate, but 2020 data showed an average volume of 57 orders per day and peaks as high as 97 orders per day.

[1] Cobb, Michael D. "Framing Effects on Public Opinion about Nanotechnology." *Science Communication* **2005**, 27(2).

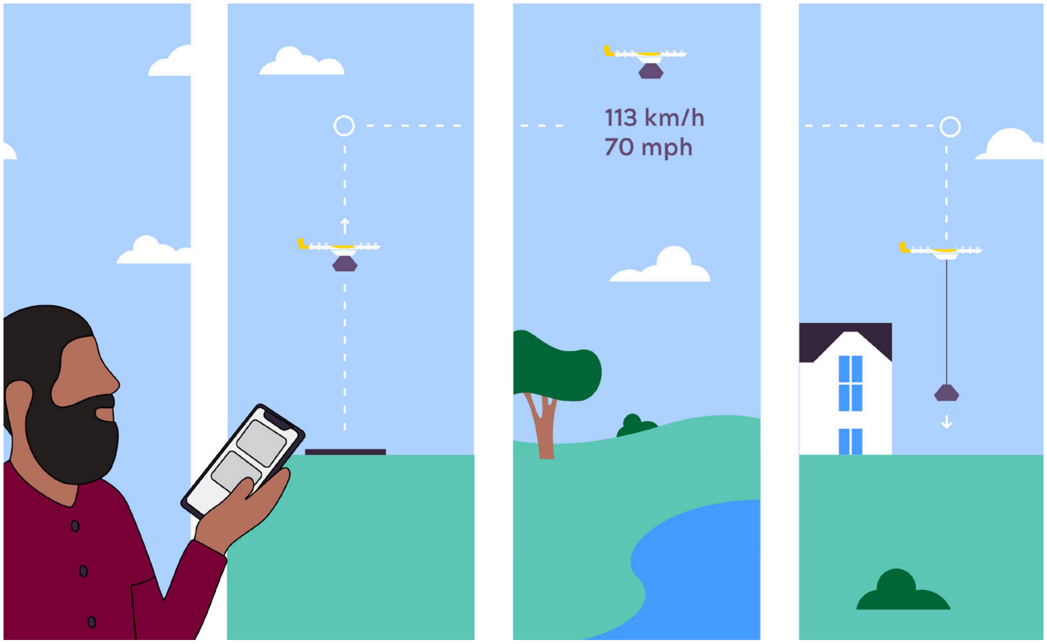

Figure 2.
Each drone delivery is initiated when a user places an order through Wing's app. After the package is loaded at Wing's operations center, the drone flies autonomously to a predetermined drop-off site at the user's address and lowers the package to the ground. Customers must be home to receive their deliveries.

Wing launched the trial in collaboration with the Virginia Tech Mid-Atlantic Aviation Partnership (MAAP), an FAA-designated UAS test site that has worked with Wing on drone integration research projects since 2016. MAAP's research and testing supported Wing's application for Air Carrier certification from the FAA, which they received in April 2019 — the first drone company to earn the certificate, which allows commercial deliveries of goods on demand. The Christiansburg trial launched in October of that year. All this work unfolded under the UAS Integration Pilot Program (IPP), a federal drone-integration initiative that brought together state agencies, local governments, and companies to collaboratively develop strategies for expediting the rollout of UAS applications with significant benefits to communities. (The ongoing trial now falls under the umbrella of BEYOND, the successor program to the IPP.)

One of the central goals of the IPP was to understand community sentiment around the introduction of drone technology, understood by the FAA to be a key element guiding UAS integration from both commercial and regulatory perspectives. For this reason, community outreach was a major component of MAAP's work under the IPP, particularly for Wing's package delivery trial. Wing and MAAP conducted several months of outreach to local stakeholders and the general public prior to the launch of the service, which provided the opportunity to familiarize the community with the technology and understand and respond to any concerns.

However, because these outreach activities necessarily occurred prior to the launch of service, the community's feedback reflected speculation about what the service would be like rather than firsthand experience. Conducting a survey after the service had been operational for some time provided a unique opportunity to quantitatively assess public sentiment around drone delivery in a community that had actually experienced it.

Survey design and content

The research team comprised representatives from MAAP and an assistant professor in the Department of Science, Technology, and Society who is an expert on human responses to technological change. The primary goal of the survey was to capture public perceptions of drone delivery in this unique sample group without introducing potential bias. To identify possible correlations between sentiment about drone delivery and factors such as education, income, family composition, and general attitude towards technology, the survey began with a standard array of demographic questions and one psychographic question about adoption of new technology. These were followed by questions that asked respondents to rank their sentiment towards the idea of drone delivery and how likely they were to use it on Likert-type scales (e.g. like a great deal / like a moderate amount / *etc.*). In order to avoid priming respondents by suggesting specific positive or negative attributes of drone delivery, the survey instead posed the open qualitative questions, “What are the positive parts of drone delivery in your opinion?” and “What are the negative parts of drone delivery in your opinion?”

The survey also asked respondents if they were familiar with Wing’s service; if so, how they had heard about it (*e.g.* from a friend, in the media, interacting with Wing staff at an outreach event); and if their opinion of drone delivery in general had changed after learning about Wing. Answers to these questions will probe the influence of familiarity on sentiment in more detail and provide insights on outreach methods.

The survey was administered in the fall of 2020, well into the COVID-19 pandemic. This unique set of circumstances might be expected to increase the appeal of services that provided access to goods without human contact; accordingly, one survey question asked how and whether the pandemic had shaped the respondent’s perception of drone delivery.

Feedback received from the Christiansburg community during outreach events reinforced the observation that opinions about drone delivery are often influenced by opinions about other, more well-established uses for drones, in particular military and hobbyist applications. For this reason, the survey asked if respondents perceived delivery drones more positively or more negatively than drones for other purposes. (This question was deliberately placed at the end of the survey to avoid influencing responses to other survey questions.)

The survey content and data management plan were reviewed and approved by the Virginia Tech Institutional Review Board (IRB # 20-678). Funding for survey distribution was provided by Wing through an existing research contract with MAAP. Respondents were recruited (*1*) via a mailer sent to 13,774 households in Christiansburg the week of November 18 and again the week of November 25 and (*2*) via a geo-targeted Facebook ad which ran November 19 - 30. Virginia Tech invited survey respondents to participate in a drawing for small ($25 - $50) gift cards to local businesses. Eligibility was not contingent on responses to survey questions, and contact information collected for participation in the drawing was not connected in any way to an individual’s responses.

Primary Findings

The survey received 834 responses; 821 were considered suitable for inclusion in analysis. One response was excluded because the respondent was not over 18, and 12 were excluded because respondents lived outside of the target geographical area, restricted for simplicity to Montgomery County (most county residents are likely to do some of their shopping in Christiansburg, where the region's major national retailers are located). Survey data was reviewed by two Virginia Tech statisticians for validity and precision. For all the values reported in this section, a 95% confidence interval bounds values no more than five percentage points in either direction from the stated value. (See Appendix for complete tables, including confidence intervals.)

Of 821 included respondents, 87% reported positive sentiments about the idea of drone delivery. The specific sentiment with the highest percentage of responses was "like a great deal" (53%) followed by "like a moderate amount" (26%) and "like a little" (8%). Only 7% reported negative sentiment across three categories of dislike ("dislike a great deal"; "dislike a moderate amount"; and "dislike a little"). Six percent of respondents reported neutral sentiments.

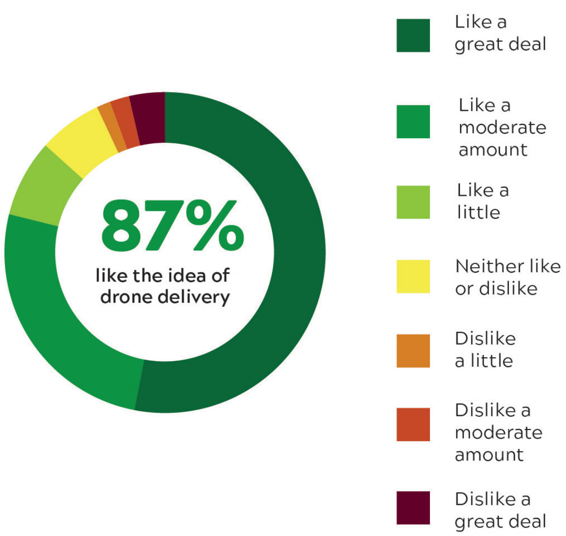

Figure 3. Respondents were asked to rate how much they liked the idea of drone delivery on a scale that included seven categories from "dislike a great deal" to "like a great deal."

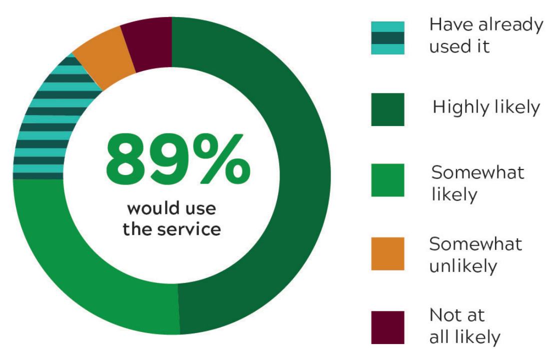

Figure 4. Respondents were asked how likely they were to use drone delivery if it were available to them. (Not all Christiansburg residents live within Wing's delivery radius.) "I have already used it" was offered as an option, to distinguish current users (teal/green stripes) from the remainder of the group.

Of 821 included respondents, 89% had either already used the service or reported that they were likely to if it were available to them. The remaining 11% were evenly split between "somewhat unlikely" and "not at all likely."

Responses to the qualitative question addressing the positive aspects of drone delivery largely focused on speed and convenience, with some respondents citing specific advantages for older adults, individuals with mobility challenges, or families with children. Other common responses included environmental benefits, reduced traffic, and contact-free delivery in the context of the COVID-19 pandemic.

In the set of responses addressing the negative aspects of drone delivery, noise was cited most frequently. Other common concerns were privacy, service limitations (e.g. delivery radius, package weight, item selection, and weather restrictions), potential job loss, impersonality in commerce, safety concerns (particularly with respect to other aircraft), and risk for delivery errors.

The majority of respondents (58%) reported that the COVID-19 pandemic had improved their opinion about drone delivery. Only 1% reported that their opinion had changed in a negative direction; 41% reported that the pandemic had not changed their opinion about drone delivery.

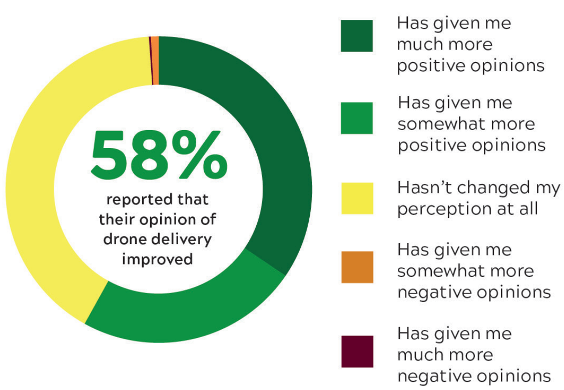

Figure 5. Respondents were asked how the COVID-19 pandemic had changed their perceptions of delivery drones.

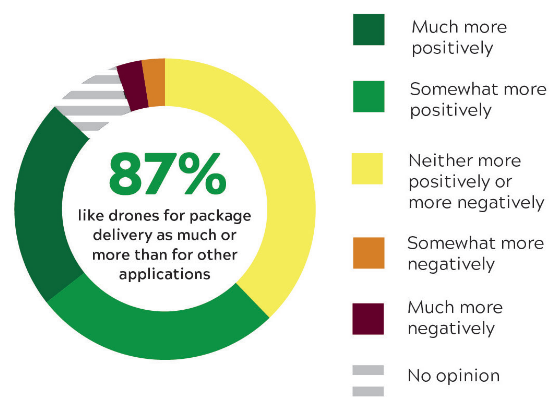

Figure 6. Respondents were asked if they perceived delivery drones more positively or more negatively than drones for other purposes. No purposes were specified in the question.

Regarding the appeal of drones used for package delivery versus other applications, 49% of respondents reported liking the idea of drones used for package delivery more than drones used for other purposes; 38% of respondents were neutral. Only 5% reported viewing delivery drones more negatively than drones used for other purposes (the remainder selected "no opinion").

More detailed analysis, including correlations between demographic and psychographic factors and sentiment, will be forthcoming in later publications.

Discussion

Previous surveys[2,3] conducted in the U.S. have found support for drone delivery hovering around 50%; support is lower in Europe and the U.K.[4,5], and delivery is a relatively unpopular application for drones when ranked against others. However, these surveys polled individuals who were almost certainly speculating about a technology they had not actually experienced. In Christiansburg, where drone delivery is an everyday reality for some residents and a familiar idea for many others, positive sentiment as measured by this survey was 87%. Similarly high percentages reported being likely to use the service, and feeling at least as positively about drone delivery as for other applications. These remarkably positive results suggest that sentiment towards drone delivery may be generally higher in communities that have experienced it. In fact, a long tradition of studies of innovation suggests that familiarity increases positive sentiment generally.[6] Future research should interrogate this more specifically by surveying populations before and after a service launch.

It is important to note, however, that while a sample group uniquely familiar with drone delivery was a primary distinguishing feature of this survey, other major factors may be relevant. A high percentage of the survey respondents reported being generally receptive to new technology, which might be expected to include drone delivery. In addition, Christiansburg's proximity to Virginia Tech, a large university with a strong engineering program, may contribute to positive sentiment in two ways. First, the presence of the university boosts the average level of educational attainment in the population, a factor consistently correlated with early adoption of new technologies. (Among survey respondents, about 62% reported having a bachelor's degree or higher, in contrast to about 33% in the general U.S. population.[7]) Demographic data did not indicate a relationship between degree attainment and sentiment within this population; nevertheless, the university may have a more generalized effect. A significant fraction of Christiansburg residents are affiliated with Virginia Tech in some way: They are alumni or employees, have family members who fall into those categories, or follow the school's popular football team. The community may, therefore, have been

[2] "How Americans view drone safety and privacy." The Hawthorn Group, November **2019**.
[3] "Autonomous Delivery Systems: Consumer Awareness & Favorability Study." Consumer Technology Association, May **2020**.
[4] "Public Perceptions: Drones." Institution of Mechanical Engineers, **2019**. (United Kingdom)
[5] "Traffic solution or technical hype: Representative population survey on delivery drones and air taxis in Germany." Sky Limits, **2020**.
[6] Rogers, Everett. *Diffusion of Innovations*. Simon and Schuster, **1962**.
[7] "Educational Attainment in the United States: **2019**." U.S. Census Bureau, Current Population Survey Annual Social and Economic Supplement.

predisposed to feel favorably about the drone delivery program because of its association with the university — highly visible since 2016, when Wing conducted their first public U.S. tests at Virginia Tech, and reinforced by the joint outreach program.

Second, the research team deliberately designed the flow and content of survey questions to avoid creating either positive or negative associations. Other recent surveys on this topic have asked questions with a strongly negative inherent bias. For example, one U.S. survey asked respondents how strongly they agreed with the statement "Commercial drones used for small scale and cargo deliveries will cause a serious accident sooner or later," whether they thought using drones for neighborhood deliveries was "too dangerous," and asked them to rank how concerned they were about safety[2]; a German study asked if respondents agreed that "drones should not be put to use for parcel deliveries at all as a matter of principle[5]. Several surveys have explicitly asked about specific concerns including privacy, national security, injuries to people and property, and disruption to air travel[4,5]. While all of these concerns appeared in responses to the question "What are the negative parts of drone delivery in your opinion," giving respondents the opportunity to offer their own answers, rather than priming responses by suggesting risks, may allow for a more accurate reflection of sentiment.

Conclusive findings on the effect of survey construction and content on reported sentiment is beyond the scope of this work. However, it is worth considering whether the deliberate neutrality of this survey may have contributed to more positive — and potentially more representative — reported sentiment. These issues should be considered in the development of future surveys on this topic.

Beyond implications for survey design, this research also contains suggestive findings for best practices around public outreach. Notably, when asked to select all the ways in which they had been exposed to the service, only 16% of respondents reported receiving a drone delivery and 16% reported interacting with Wing staff at outreach events. However, 77% reported having heard about the service through the media — by far the largest category. This underscores the importance

of conducting broad education and awareness campaigns that utilize a range of different channels, including local media. The qualitative responses about perceived positive and negative aspects of drone delivery are also a rich source of insight for future outreach efforts, indicating a community's potential needs and concerns and informing the development of effective messaging.

The COVID-19 pandemic sparked an increase in Wing's order numbers and new customer sign-ups. The company partnered with new local merchants, which expanded the options available to their customers and provided businesses with a valuable way to continue to earn revenue. Working with a local librarian, they began delivering books from the school library system. Anecdotal reports suggested that the community appreciated the availability of no-contact deliveries, access to some of their favorite foods, and the boost for local businesses. This hypothesis was borne out by the majority (58%) of respondents who indicated that their opinion of drone delivery had improved since the pandemic, as well as by the many responses to the open-ended question about benefits of drone delivery that referenced the pandemic, such as "contact free," "not having to go out for small items during covid [*sic*]," and "Hands off especially no contact in the midst of the pandemic." (Note that the question about the pandemic appeared later in the survey than this open-ended question, and could not have prompted COVID-related answers; these associations were offered spontaneously.) These results differ somewhat from those of another 2020 survey[3], in which only 26% of respondents reported that their opinion of drone delivery had improved following the pandemic; 60% reported no change, and 14% reported that their opinion had deteriorated. The larger jump in positive opinion in the Christiansburg survey may be related to the respondents' observations — or direct experience of — of ways the technology had mitigated the impacts of the pandemic in their own communities.

Conclusion

This Virginia Tech survey provides the first known measure of public sentiment towards drone delivery in which the survey population was familiar with the service in their own community and, in some cases, had actually used it themselves. This offered a unique opportunity to estimate potential public response to a technology still in the nascent stages of commercial rollout but likely to become more widespread over the next five to ten years. In the survey, 87% of respondents reported positive overall sentiment, a similar number reported that they had already used the service or were likely to, and a large percentage reported feeling more positively about the use of drones for package delivery than for other applications. These results are all significantly more favorable than other recent studies on the same topic but whose survey populations had no firsthand experience. In addition to being a promising sign for the future of drone delivery in the U.S., the nature of these results has useful implications both for survey design and outreach strategies. Those insights, in addition to the primary survey outcomes, have the potential to shape the rollout of drone services by facilitating more accurate research and more effective public engagement — all of which will provide invaluable guidance for policymakers, communities, and governments as they work together to advance safe UAS integration to the benefit of the public.

Appendix

Table I. General sentiment towards drone delivery

Question: Please tell us how much you like the idea of drone delivery on the following scale.

Response	Count	Probability	Lower confidence interval (CI)	Upper confidence interval (CI)	1-Alpha
Like a great deal	436	0.53106	0.496859	0.564971	0.950
Like a moderate amount	213	0.25944	0.230626	0.290494	0.950
Like a little	63	0.07674	0.060436	0.096978	0.950
Neither like nor dislike	53	0.06456	0.049691	0.083476	0.950
Dislike a little	12	0.01462	0.008381	0.025373	0.950
Dislike a moderate amount	15	0.01827	0.011103	0.029925	0.950
Dislike a great deal	29	0.03532	0.024705	0.050269	0.950
Total	**821**				

Table II. Likelihood of using the service

Question: If it was available to you, how likely are you to use a drone delivery service?

Response	Count	Probability	Lower CI	Upper CI	1-Alpha
I have already used it.	119	0.14495	0.122517	0.17068	0.950
Highly likely	405	0.49330	0.459213	0.527451	0.950
Somewhat likely	209	0.25457	0.22596	0.285461	0.950
Somewhat unlikely	43	0.05238	0.039114	0.069806	0.950
Not at all likely	45	0.05481	0.041214	0.072555	0.950
Total	**821**				

Table III. Effect of the pandemic on sentiment

Question: How has the COVID-19 pandemic changed your perception of delivery drones?

Response	Count	Probability	Lower CI	Upper CI	1-Alpha
It hasn't changed my perception at all.	283	0.34470	0.312983	0.377867	0.950
It has given me much more positive opinions about drone delivery.	194	0.23630	0.208509	0.266542	0.950
It has given me somewhat more positive opinions on drone delivery.	336	0.40926	0.376122	0.443238	0.950
It has given me somewhat more negative opinions on drone delivery.	2	0.00244	0.000668	0.008838	0.950
It has given me much more negative opinions on drone delivery.	6	0.00731	0.003354	0.01582	0.950
Total	**821**				

Table IV. Delivery versus other applications

Question: Do you perceive delivery drones more positively or more negatively than drones used for other purposes?

Response	Count	Probability	Lower CI	Upper CI	1-Alpha
I view delivery drones much more positively than drones for other purposes.	219	0.26675	0.237633	0.298035	0.950
I view delivery drones somewhat more positively than drones for other purposes.	186	0.22655	0.199231	0.256422	0.950
I view delivery drones neither more positively or more negatively than drones for other purposes.	311	0.37881	0.346462	0.41248	0.950
I view delivery drones somewhat more negatively than drones for other purposes.	20	0.02436	0.015824	0.037327	0.950
I view delivery drones much more negatively than drones for other purposes.	23	0.02801	0.018739	0.041686	0.950
I have no opinion about this distinction.	62	0.07552	0.59355	0.095634	0.950
Total	**821**				