CCALS Commonwealth Center for Advanced Logistics Systems

Advanced Air Mobility Implementation

in the

Commonwealth of Virginia

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Introduction to Advanced Air Mobility (AAM)

Advanced Air Mobility (AAM) represents the next frontier in aviation, promising to revolutionize how people and goods are transported over short and medium distances. Unlike traditional aviation, AAM focuses on using electric vertical take-off and landing (eVTOL) vehicles and other advanced aircraft to operate within urban, suburban, and rural environments. AAM envisions a future where transportation is faster, more flexible, and environmentally sustainable, addressing the limitations of current transportation systems and creating new opportunities for mobility. The development of AAM is often referred to as the third flight revolution, following the introduction of the jet engine and the rise of commercial airliners. This revolution is driven by advancements in electric propulsion, automation, and air traffic management, enabling new forms of mobility that are more efficient and less dependent on traditional infrastructure.

Types of AAM

AAM encompasses a wide range of vehicles and applications, each designed to address specific transportation needs:

Urban Air Mobility (UAM):

Urban Air Mobility focuses on short-distance travel within urban areas, using eVTOL aircraft to provide air taxi services and reduce congestion. UAM can offer on-demand mobility, complementing existing public transport systems and providing an alternative to road-based travel in densely populated areas.

Regional Air Mobility (RAM):

Regional Air Mobility covers longer distances, connecting cities and regions with eVTOLs or hybrid-electric aircraft. This type of mobility aims to provide a faster alternative to road and rail travel, particularly in areas where traditional infrastructure is lacking or inefficient. For example, the Electra.Aero vehicle being designed in VA is ideal for regional transport, offering a range of up to 500 miles.

Cargo Air Mobility:

Cargo Air Mobility involves using specialized aircraft to transport goods, ranging from small packages to heavy cargo. This category includes autonomous drones and airships, which can operate in remote areas or deliver goods to urban centers more efficiently than traditional methods. NASA Aeronautics Research Institute emphasizes the potential of AAM for cargo delivery, particularly in rural areas where access to essential goods can be challenging.[1]

Military and Emergency Services:

AAM can also be adapted for military and emergency applications, providing rapid and flexible transport solutions in critical situations. For example, eVTOLs can be used for medical evacuations, disaster response, or transporting military personnel between key locations.

Cost and Uses of AAM

The cost of implementing AAM infrastructure and operations varies widely depending on the type of vehicle, the scale of deployment, and the specific use case. However, the potential benefits justify these investments:

Urban Air Mobility (UAM):

- The cost of UAM services is expected to decrease as technology matures and economies of scale are achieved. Initial estimates suggest that air taxi fares would be twice the cost of current ride-sharing services, overtime falling to be comparable as the technology matures, making UAM an accessible option for many urban dwellers according to an MIT Report on Demand Potential for Urban Air Mobility.[2]

Transport mode	Distance variable cost (per passenger $/km)	Time variable cost ($/min)	Fixed cost
UAM, near term	$3.56 - $3.88	-	-
UAM, long term	$1.14 - $1.55	-	-
Car, dropped off	$0.437	-	-
Car, parked for 3 days	$0.437	-	$36.00
Transportation Network Company (TNC) (i.e., on-demand car rides)	$0.665	$0.17	$6.80
Taxi	$1.86	-	$3.23
Public Transit	-	-	$6.00

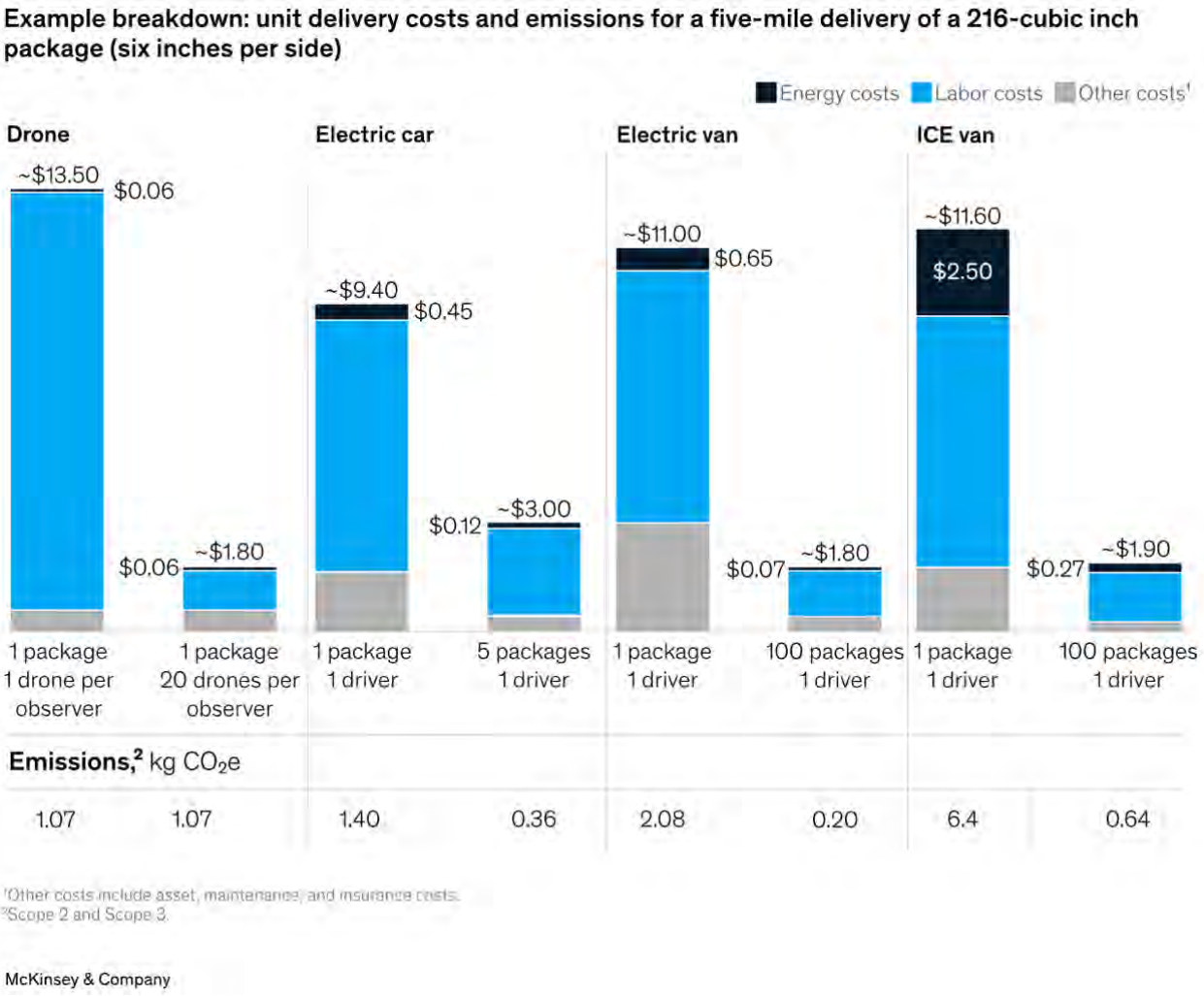
Demand Potential for Urban Air Mobility, MIT and EVE

Regional Air Mobility (RAM):

- The benefits include faster travel times between cities and regions, reduced dependence on road and rail networks, and improved accessibility for remote areas. RAM could play a crucial role in connecting underserved regions, particularly in areas where traditional infrastructure is lacking.

Cargo Air Mobility:

- The cost of cargo AAM services will depend on the payload capacity, range, and operational scale of the vehicles used. There are no concrete studies at the moment assessing the cost of long range or large scale cargo transport, but small drones designed for last-mile delivery are relatively affordable comparable in cost to current delivery methods[3]. While larger airships designed for heavy cargo transport would have higher initial costs, their overall cost per kg/mile would be much lower. The NASA Rotary Conference presentation highlights the potential for AAM to transform cargo delivery, particularly in rural and remote areas where access to essential goods can be challenging. [1]



Military and Emergency Applications:

- AAM is already being implemented in the military, the U.S. Airforce was one of the first orders delivered by Joby. The benefits of rapid deployment, flexible operations, and improved access to remote areas make AAM a valuable tool for these applications.

Pros and Cons of AAM

Pros:

- **Economic Benefits:** The development of Advanced Air Mobility (AAM) in Virginia is projected to generate $16 billion in new business activity, boost the aerospace sector's growth by 10%, and produce $2.8 billion in local, state, and federal tax revenues. Additionally, AAM will create over 17,000 new full-time jobs across diverse sectors, enhancing opportunities in both urban and underserved areas. These advancements will attract AAM manufacturers and foster innovation, contributing significantly to Virginia's economy.[4]
- **Increased Accessibility:** AAM can provide access to remote or underserved areas, enhancing connectivity and economic opportunities. This is particularly important in rural regions, where traditional transportation options may be limited.
- **Environmental Benefits:** AAM vehicles, particularly eVTOLs, are designed to be more environmentally friendly than traditional aircraft and ground vehicles. By using electric propulsion, they produce fewer emissions and are quieter, reducing their impact on urban environments.
- **Flexibility:** AAM services are designed to be on-demand, providing flexibility in terms of route planning and scheduling. This can reduce the need for fixed infrastructure and enable more efficient use of resources.

Cons:

- **Infrastructure Challenges:** Implementing AAM may requires significant investment in new infrastructure, including vertiports, charging stations, and eventually air traffic management systems for autonomous adoption. These investments are necessary to support the safe and efficient operation of AAM vehicles, particularly in urban areas.
- **Regulatory Hurdles:** Developing the necessary regulations to ensure the safety and integration of AAM into existing airspace will be a complex and time-consuming process. Regulatory agencies such as the FAA and EASA are already working on these issues, but it will take time to develop and implement the necessary frameworks.
- **Public Acceptance:** The success of AAM will depend on public acceptance, which could be influenced by concerns about noise, safety, and the visual impact of AAM vehicles. Efforts to engage with communities and address these concerns will be crucial for the successful adoption of AAM.
- **High Initial Costs:** The initial costs of developing and deploying AAM technology will be high, particularly for infrastructure and vehicle development. However, these costs are expected to decrease over time as the technology matures and economies of scale are achieved.

Viability Timeline and Projects of Interest

The timeline for AAM viability is influenced by various factors, including technological advancements, regulatory approvals, and public acceptance. Plausible timelines for AAM introduction and the associated infrastructure implications are discussed in [5] and [6]. Based on current trends and projections, the following timeline can be expected:

- **Short-term (2024-2026):** Early pilot projects and small-scale deployments will likely focus on urban air mobility and cargo delivery. Cities such as New York, LA and San Francisco, are expected to be early adopters of AAM technology.
- **Mid-term (2027-2035):** As more cities and regions develop the necessary infrastructure and regulatory frameworks, AAM adoption will accelerate. This period will likely see the expansion of commercial air taxi services, regional air mobility networks, and the integration of AAM into existing transportation systems.
- **Long-term (2036 and beyond):** Widespread integration of AAM into global transportation networks will occur as the technology matures and becomes more accessible. By this time, AAM is expected to be a standard part of the transportation ecosystem, with fully established infrastructure and optimized operations.

Aircraft	Type	Use	Payload Capacity	Range	Status	Expected Certification/Productio
Volocopter VoloCity	eVTOL	Air taxi	2 passengers	22 miles	EASA certification in progress	2024
Joby Aviation eVTOL	eVTOL	Air taxi	4 passengers + pilot	150 miles	FAA certification in progress	2025
Lilium Jet	eVTOL	Regional transport	6 passengers	TBD	Certification in progress	2025
Archer Midnight	eVTOL	Air taxi	4 passengers + pilot	100 miles	FAA certification in progress	2024
Autoflight Prosperity 1	eVTOL	Air taxi	3 passengers + pilot	150 miles	EASA certification in progress	2025
EHang EH216	Autonomous Aerial Vehicle (AAV)	Air taxi	2 passengers	21 miles	Chinese certification in progress	2025
Vertical Aerospace VX4	eVTOL	Air taxi	4 passengers + pilot	100 miles	Certification in progress	Mid-2020s
Beta Technologies ALIA-250	eVTOL	Cargo transport	1,400 pounds	250 miles	Advanced development, FAA certification in progress	2027
Elroy Air Chaparral	VTOL Hybrid-Electric	Autonomous cargo delivery	500 pounds	300 miles	Advanced testing, certification in progress	2025
Sabrewing Rhaegal	VTOL Hybrid-Electric	Heavy cargo transport	5,400 pounds	1,000 nautical	Prototype phase, certification in progress	TBD
Dronamics Black Swan	Fixed-Wing UAV	Cargo transport	770 pounds	1,500 miles	Late-stage development, certification in progress	Near future
Natilus N3.8T	Autonomous Cargo Aircraft	Heavy cargo transport	8,500 pounds	1,800 nautical	Prototype phase, certification in progress	2025
EHang Falcon (Falcon B)	Autonomous Aerial Vehicle (AAV)	Cargo delivery	440 pounds	30 miles	Extensive testing, certification in progress	Near future
Wingcopter 198	Fixed-Wing eVTOL Drone	Cargo delivery	13 pounds	47 miles	Ramping up production, certification in progress	Soon
Volocopter VoloDrone	eVTOL	Heavy-lift cargo transport	440 pounds	25 miles	Testing and certification	Near future
Pyka Pelican Cargo	Autonomous Fixed-Wing Aircraft	Cargo delivery	400 pounds	200 miles	Test flights and development, certification in progress	Near future
Zipline Platform 2 (P2)	Fixed-Wing UAV	Small package delivery	8 pounds	100 miles	Operational in some regions, certification in progress	Scaling up production
Hybrid Air Vehicles Airlander 10	Hybrid Airship	Cargo and passenger transport	22,000 pounds (10 metric tons)	4,000 nautical	Preparing for production	2026
Lockheed Martin LMH-1	Hybrid Airship	Cargo and passenger transport	20 tons	TBD	Advanced development	TBD
Flying Whales LCA60T	Rigid Airship	Heavy cargo transport	60 tons	TBD	Advanced development	2027
Atlas LTA Nova D-1000	Rigid Airship	Heavy cargo transport	60 tons	TBD	Advanced development	TBD
Varialift Airships	Rigid Airship	Heavy cargo transport	Up to 250 tons	Long-range	Prototype testing	Near future
Aeroscraft ML866	Rigid Airship	Cargo and passenger transport	66 tons	TBD	Prototype development	TBD
MightyFly Cento	Hybrid Airship	Cargo	100 pounds	600 miles	Advanced development and FAA testing	Near future
Electra.Aero	eSTOL	Passengers or Cargo	9 passengers +50 lb. luggage each or 2,500 lb. of cargo	500 miles	Advanced development	TBD

AAM vehicle's, their stats and expected certification timeline, CCALS, Sofoniase Zeraye

AIR TAXI

OEM	ARI
Volocopter	8.6
Joby Aviation	7.9
Archer	7.9
Aerofugia	7.4
Wisk	7.4
Eve Air Mobility	7.2
Vertical Aerospace	7.1
AutoFlight - Prosperity I	6.8
SkyDrive	6.7
Supernal	6.5
Volant Aerotech	6.4

REGIONAL

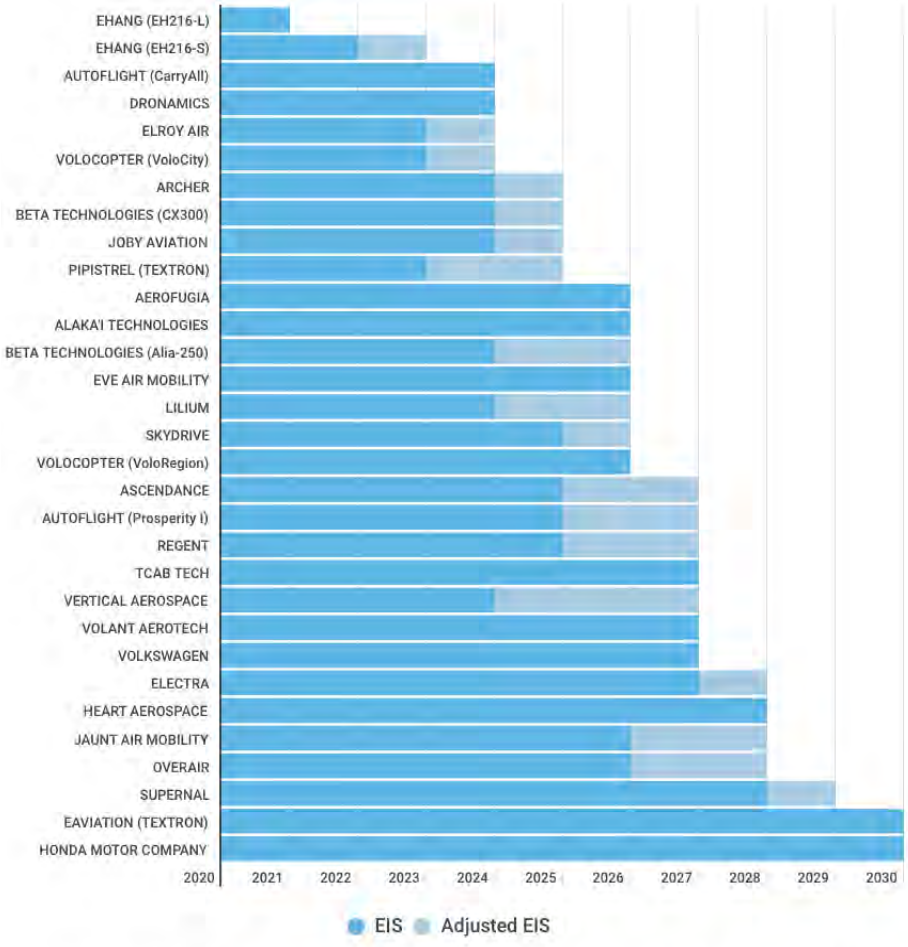
OEM	ARI
Lilium	7.0
Eviation	6.2
Ascendance	6.2
REGENT	6.1
Electra	5.4
Heart Aerospace	5.1

CARGO

OEM	ARI
AutoFlight - CarryAll	8.5
Beta Technologies	8.0
Pipistrel (Textron)	7.0
Elroy Air	6.8
Dronamics	6.6
Ehang - EH216-L	6.0

OTHERS

OEM	ARI
Ehang	8.5
Airbus	7.4
eAviation (Textron)	5.9
Dufour Aerospace	5.7



Light colored bars show changes from baseline; AIRBUS, DUFOUR AEROSPACE, EVIATION and WISK have not announced an EIS date; EHANG has not announced an EIS date for the VT-30 eVTOL

Baseline: July 14, 2021

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Advanced Air Mobility (AAM) is on the verge of becoming a mainstream technology, with numerous companies racing to be the first to reach the market. The graph to the top left shows the AAM reality index (ARI) which evaluates several AAM companies. The index assigns a score from 0 to 10, based on factors such as vehicle development status, with higher scores indicating a greater likelihood of the products successfully entering the market. The second graph compares the initial Entry Into Service (EIS) projections made by the companies with the adjusted EIS timelines. These metrics were developed by SMG Consulting. Despite significant advancements in the industry, a reliable timeframe for mass adoption has yet to be established. [7]

Projects of Interest:

Joby Aviation is one of the most well-funded projects in the eVTOL space, with plans to certify its vehicle with the FAA by 2025. The aircraft is designed to carry four passengers up to 150 miles at speeds of 200 mph, making it a leading candidate for urban air taxi services.[8]

JOBY AVIATION
eVTOL

VOLOCOPTER
VOLOCITY

Volocopter was planning commercial operations in Paris for the 2024 Summer Olympics, this plan didn't come to fruition, but they still hope to achieve EASA certification for its urban air taxi service by 2024. The VoloCity is designed for short-range urban transport, with a range of up to 22 miles.[9]

Lilium is developing a six-passenger eVTOL jet for regional air mobility, with a targeted range of 150 miles. The company expects to achieve certification by the end of 2025, making it a key player in the regional air mobility market.[10]

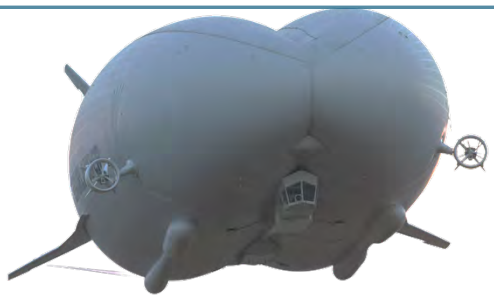
LILIUM
JET

ARCHER
MIDNIGHT

Archer is developing the Midnight, an eVTOL designed for rapid, back-to-back trips with a range of up to 100 miles. The company expects to achieve FAA certification in 2024 and begin commercial operations shortly thereafter.[11]

Autoflight is developing the Prosperity 1, a four-person air taxi with a range of 150 miles. The company is targeting EASA certification by 2025, making it a potential contender in the European market for urban air mobility. [12]

AUTOFLIGHT
PROSPERITY I



HYBRID AIR VEHICALS
AIRLANDER 10

HAV is developing the Airlander 10, a hybrid airship with a range of 4000 nautical miles and load capacity of 10 metric tons. The company is expecting certification by 2026. The company hopes to rollout luxury novelty flights to places such as the north pole in the coming years.[13]

Flying Whales a French company is developing a cargo transport Ridged airship with a load capacity of 60 tons. The company plans to start flying its prototype sometime next year and expects certification by 2027.[14]

FLYING WHALES
LCA60T

Electra.Aero

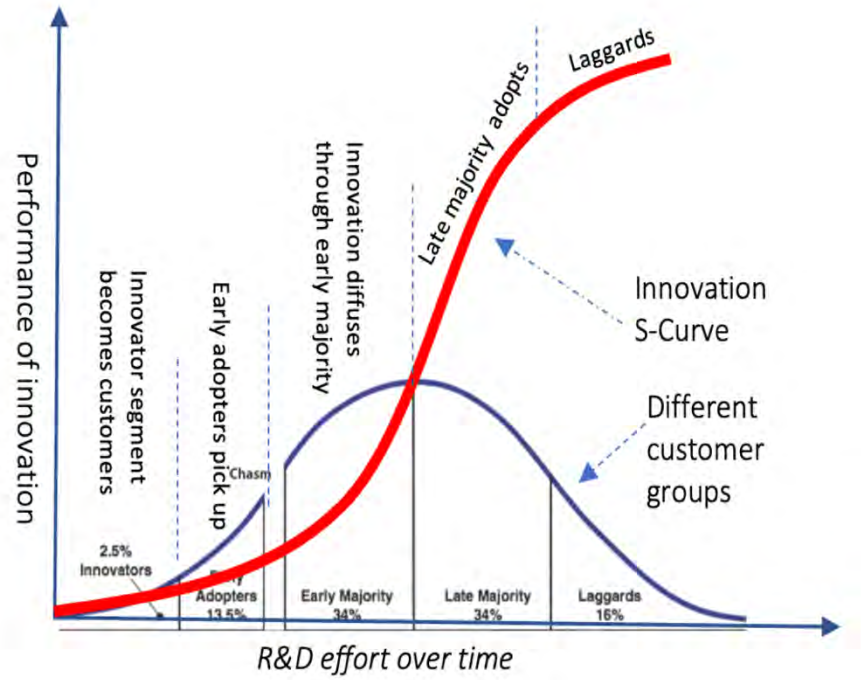
Electra.Aero Is a Virginia based company developing a hybrid short take off vehicle. The vehicle can cruise at 200mph with a payload of 2500lb and can take off/land from a 300ft runway. [15]

Beta Technologies is developing the ALIA-250 designed for cargo and passenger transport. The aircraft features a range of 250 miles. Beta is targeting 2025 for FAA certification for its conventional takeoff model and 2027 for the eVTOL.[16]

BETA Technologies
ALIA-250

The S-Curve of Adoption

The adoption of AAM technology is expected to follow the classic S-curve model, characterized by an initial slow uptake due to high costs, limited infrastructure, and regulatory challenges, followed by rapid growth as these barriers are overcome. The mid-term will see significant expansion as technology matures and public acceptance increases, leading to widespread adoption and integration into existing transportation networks. By the maturity phase, AAM will be a standard part of the global transportation ecosystem, with fully established infrastructure and optimized operations. Currently AAM is in the very early stages of the S curve, about to enter a transitory period of adoption. This will likely be seen in the form of specialized project implementations and VIP transport. [17].



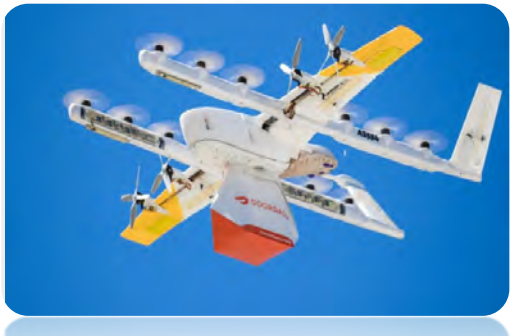
S-Curve for Technology Adoption and Adopters Over Time

Potential Applications in the Commonwealth of Virginia

The Commonwealth of Virginia presents several promising opportunities for the implementation of AAM, particularly in areas where traditional transportation systems are less effective or where new mobility solutions could provide significant benefits. Some key applications include:

Manufacturing Transport:

- Virginia's manufacturing sector could benefit from AAM by enabling the rapid transport of components and finished products between facilities. This could reduce lead times, increase efficiency, and support the state's economic growth. Virginia has an abundance of lumber in its mountainous regions, accessing this lumber and transporting it requires large investments in infrastructure. Large cargo Airships like the Flying Whale LCA60T were designed with this purpose in mind. Additional applications include cargo transport from the Port of Virginia to the Virginia Inland Port (VIP), as well as transporting cargo containers between different terminals or even directly onto the ships, saving valuable time and decongesting the heavy truck traffic that is a staple of the port. Small scale deliveries are already being implanted such as in Christiansburg, where Wing launched its first commercial drone delivery service in the United States. [18] Midsized AAM's such as Virginia's own Electra.Aero can bridge intermediary gaps with its 500-mile range, 2,500lb capacity and short take off capabilities it is a good alternative to delivery trucks. A small fleet of these vehicles could be able to support the states rural transport demands.

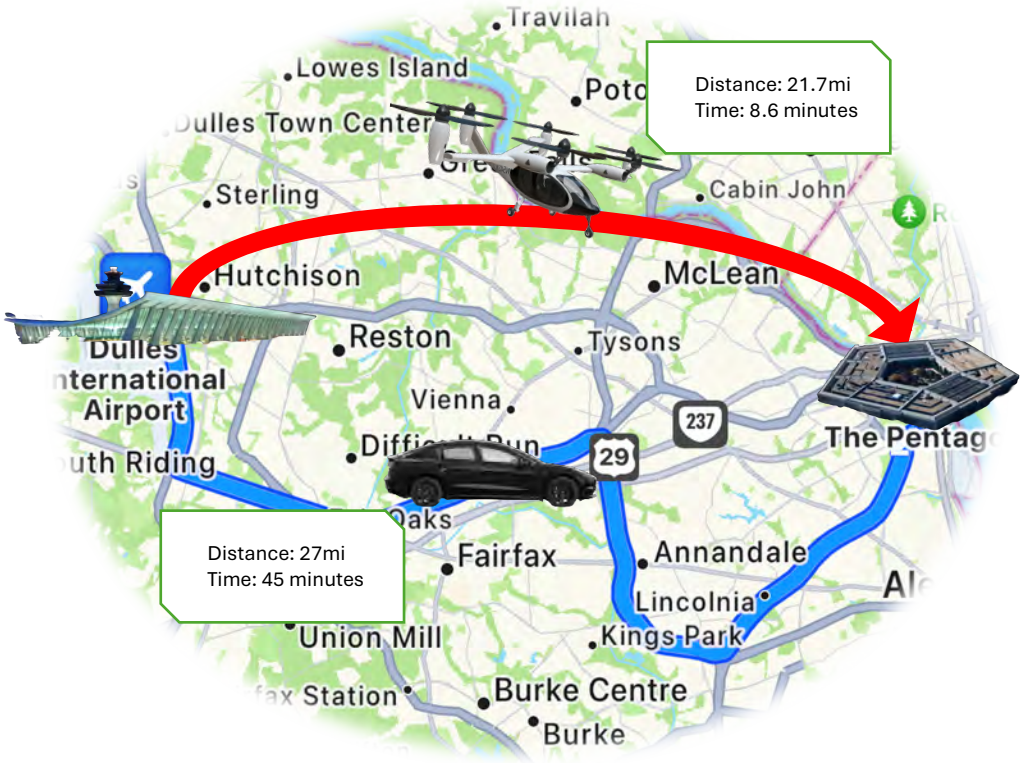


Rural Emergency Care Transport:

- AAM could play a critical role in improving access to medical care in rural areas of Virginia. By providing fast and flexible transport options, eVTOLs could be used to deliver medical supplies, transport patients to hospitals, and support emergency response efforts in remote areas. A high viability area for immediate implementation is the rapid delivery of organs for transplants The NASA Rotary Conference presentation emphasizes the potential for AAM to address the challenges of rural healthcare, particularly in regions where traditional transportation options are limited. [1]

VIP Urban and Regional Transport:

- The strategic locations of Virginia's military installations and airports makes AAM a valuable tool for transporting military personnel and VIPs between key locations. For example, eVTOLs could be used to provide secure and efficient transport between Hampton Roads (a major military hub) and the Pentagon, supporting the needs of the U.S. military and government. The commute is 3 and a half hours and 220mi, with eVTOLs the commute would be cut down to 145mi and depending on the vehicle, to less than an hour. On a local level the commute from Dulles International Airport to the Pentagon is 25mi and takes approximately 30 minutes with no traffic and upwards of an hour with traffic. With the Joby platform, the trip is cut down to 9 minutes and the noise relative to a helicopter is 25db quieter.



Time and distance Visual from Dulles international to the Pentagon, CCALS,

Preparing for the Onset of AAM Technology in the Commonwealth

To prepare for the widespread adoption of AAM technology, the Commonwealth of Virginia should take proactive steps to ensure that the necessary infrastructure, regulatory frameworks, and public support are in place. Some key recommendations include:

Designate a Governmental Agency:

- The Commonwealth should create or designate a governmental agency responsible for overseeing the implementation and planning of AAM infrastructure, regulations, and safety standards. This agency would work closely with federal agencies such as the FAA and EASA to ensure that Virginia is at the forefront of AAM adoption. One path would be to follow other states lead such as Florida and Georgia and designate the Department of Transportation as the leading body to oversee AAM adoption.

Fund Early Research:

- Virginia should invest in research to identify potential use cases for AAM within the state and conduct economic analyses to determine the feasibility and benefits of various applications as well as identifying locations for potential infrastructure integration. This research could help attract private-public partnerships and ensure that investments are made wisely, aligning with the technology's development along the S-curve.

Invest in Infrastructure at the Right Time:

- As AAM technology advances, the Commonwealth should incentivize and coordinate investment in the necessary infrastructure. These investments should be timed to coincide with key milestones in the S-curve to maximize efficiency and return on investment without exposing the commonwealth to unnecessary risks and wasting taxpayer money. A key infrastructure component to the adoption of this technology is having sufficient energy load available on the grid to support the power demands of largescale EV charging. As it stands energy demands in data centers have monopolized a majority of the new load projects on the grid. For viability of large-scale adoption sufficient investment in the electric grid is paramount.

Federal and State Initiatives in Advanced Air Mobility

Advanced Air Mobility (AAM) is not just a concept being explored by individual states or private companies; but has been supported at the federal level in the United States for a long time. The Federal Aviation Administration (FAA), National Aeronautics and Space Administration (NASA), and various state governments are actively participating in research, regulation, and infrastructure planning to support the safe integration of AAM into the national airspace.

Federal Initiatives

FAA UAS Integration Pilot Program (IPP):

- The FAA's Unmanned Aircraft Systems (UAS) Integration Pilot Program (IPP) has laid the groundwork for future AAM operations by partnering with state, local, and tribal governments as well as the Department of Defense(DoD), Congresses' Interagency Working Group(IWG) on AAM and National Level Industry groups to explore how drones and other autonomous aircraft can be safely integrated into the airspace. Lessons learned from the IPP are directly applicable to AAM, particularly in terms of air traffic management and community engagement.[19]

NASA's AAM Mission:

- NASA is leading the AAM National Campaign, which aims to accelerate the development and integration of AAM technologies. This campaign involves collaboration with industry partners to conduct flight tests, evaluate vehicle performance, and develop airspace management systems. The goal is to establish a safe, scalable AAM ecosystem that can be adopted nationwide.[20]

US Department of Transportation VOLPE center:

- The VOLPE center, supported by the U.S. Department of Transportation, aims to bring together public and private stakeholders to facilitate the research and deployment of UAM services in cities across the country. This partnership focuses on developing infrastructure, regulatory frameworks, and community engagement strategies to support the safe introduction of UAM.[21]

State-Level Initiatives

Several states are preparing for the adoption of AAM by developing infrastructure, engaging with stakeholders, and conducting pilot projects, while Virginia is entering into the arena there are many lessons the commonwealth can take from other states approaches.

Here are some notable examples:

California:

- California has been at the forefront of AAM development, with several cities exploring the potential for UAM services. Los Angeles, in particular, has partnered with Uber Elevate (now part of Joby Aviation) to explore the feasibility of air taxi services. The state is also home to several AAM companies, including Joby Aviation and Archer, which are working closely with local governments to develop vertiports and other necessary infrastructure.[22]

Texas:

- Texas is emerging as a key player in AAM, with cities like Dallas and Houston exploring the use of eVTOLs for urban air mobility. The Texas Department of Transportation (TxDOT) has been involved in discussions around the integration of AAM into the state's transportation network, focusing on how to leverage existing infrastructure like airports and highways to support AAM operations. [23]

Ohio:

- Ohio, with its rich aviation history and strong manufacturing base, is positioning itself as a leader in AAM. The state has established the Ohio UAS Center, which is involved in testing and evaluating AAM technologies. Additionally, Ohio's Department of Transportation is exploring how AAM can be integrated into the state's broader transportation network, with a focus on connecting rural areas to urban centers.[24]

Florida:

- Florida is actively pursuing AAM opportunities, particularly in the area of tourism and cargo transport. The state is home to several key aerospace companies and research institutions that are involved in developing AAM technologies. Florida's favorable weather conditions and existing aviation infrastructure make it a viable location for AAM testing and deployment.[25][26]

Virginia:

Virginia has been actively working to integrate Advanced Air Mobility into its transportation infrastructure, leveraging its aviation and technology sectors. The state has initiated several steps to position itself as a leader in AAM development. Key efforts include:

- **Infrastructure Upgrades**: Virginia's Department of Aviation (DOAV) and the Virginia Aviation Board (VAB) have allocated funding to upgrade the state's 65 public-use airports. Each airport can receive up to $200,000 to install critical infrastructure like 3-phase electrical power and broadband connectivity. These upgrades are essential for supporting AAM operations, particularly for charging eVTOL aircraft and ensuring safe communications during flights.[16]
- **Testing and Development**: Virginia Tech's **Mid-Atlantic Aviation Partnership (MAAP)** has been at the forefront of testing Unmanned Traffic Management (UTM) systems and evaluating the integration of drones and other uncrewed aerial systems (sUAS) into public airspace. MAAP's research is critical for developing safe, evidence-based practices that support AAM and related technologies.[27]
- **Public-Private Partnerships**: The state has also engaged in collaborative efforts with private companies to conduct demonstrations and tests. For example, a significant test involving sUAS was held in Winchester, where multiple operators safely managed drones in public airspace during a local event. This is part of Virginia's strategy to build a "drone-ready" infrastructure across its communities.[28]

Infrastructure Development for AAM

One of the challenges in implementing AAM is the development of the necessary infrastructure. Segments of AAM requires new types of infrastructure, such as vertiports, charging stations, and advanced air traffic management systems. These elements are crucial for the safe and efficient operation of AAM vehicles, particularly in urban areas where space is limited, and air traffic is dense.

Vertiports

Vertiports are a primary infrastructure needed for UAM operations. These facilities are designed to accommodate eVTOLs, providing spaces for take-off, landing, charging, and maintenance. Vertiports can be built in various settings, including urban rooftops, suburban areas, and existing airports. Modular and flexible vertiport designs that can be adapted to different environments and operational needs are a key component of UAM adoption.

- **Urban Vertiports:** Urban vertiports are typically integrated into existing buildings or constructed on rooftops, where space is at a premium. These vertiports must be designed to minimize noise and visual impact, while also ensuring safe and efficient operations. The report highlights the need for urban planners and architects to work closely with UAM developers to integrate vertiports into the urban fabric in a way that enhances connectivity without disrupting the community.

- **Suburban and Rural Infrastructure:** In suburban and rural areas AAM infrastructure can be larger and more spread out, often repurposing existing infrastructure like airports or industrial sites. These sites can serve as hubs for regional air mobility, connecting smaller communities to larger urban centers. These facilities should be designed with scalability in mind, allowing for future expansion as AAM adoption increases.

Charging and Energy Infrastructure

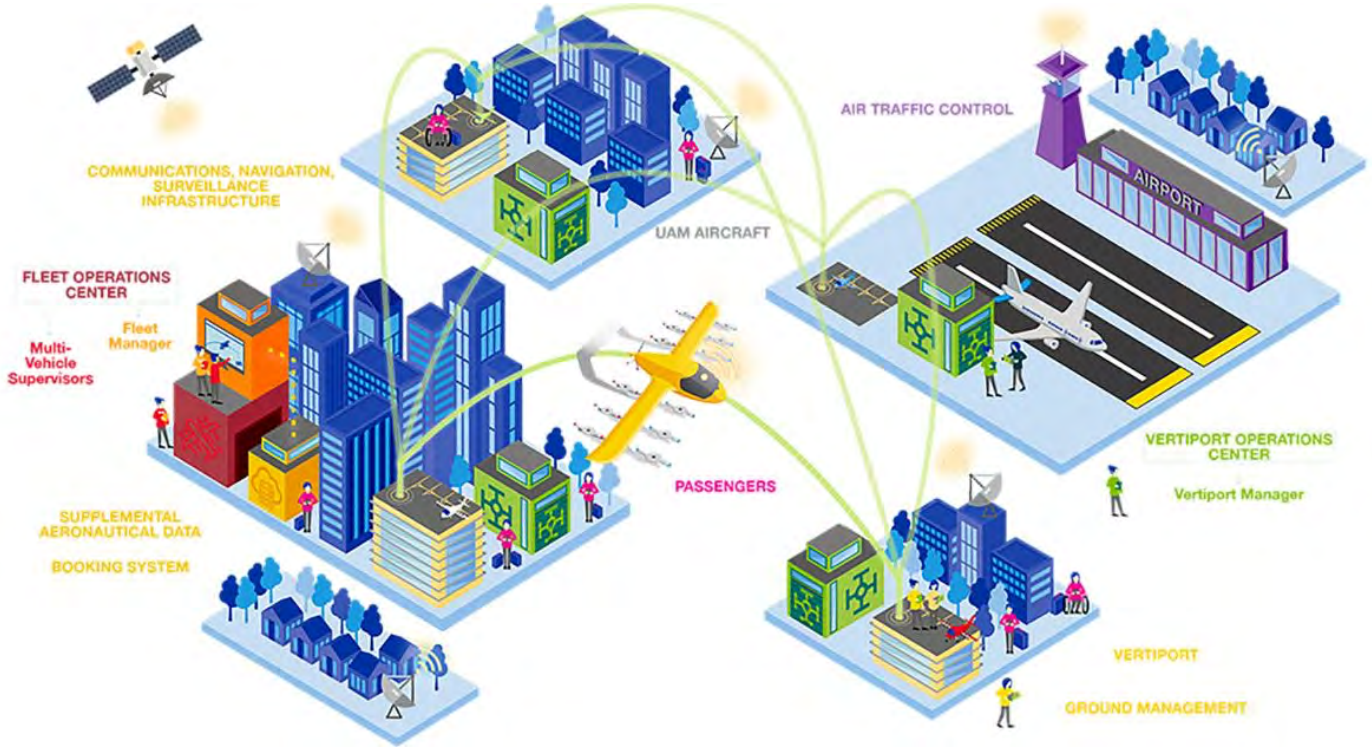
Many AAM vehicles, particularly eVTOLs, rely on electric propulsion, which requires a robust charging infrastructure.

- **Energy Demands and Competition:** Dominion Energy and the broader PJM Interconnect are experiencing significant increases in energy demand, driven primarily by data centers, the electrification of transport, and broader commercial growth. Dominion Energy projects annual peak load growth of about 5% and net energy demand growth of around 7% over the next decade, largely driven by the expansion of data centers in Virginia. Data centers already account for about 24% of Dominion's electricity sales, and these facilities are expected to grow rapidly, with individual campus requests ranging from 300MW to several gigawatts. The company added over 933MW of data center load in 2023 alone and expects this trend to continue at an accelerated pace in the coming years.[29] The PJM Interconnect, which includes Virginia, overall energy demand is expected to grow at an annual rate of 1.4% over the next decade, with summer peak loads growing by 0.8% annually. This would bring PJM's summer peak load to about 167,567 MW by 2038. The growth is fueled by increasing numbers of electric vehicles (EVs) and data center expansions, particularly in Virginia and Maryland.[29] Both Dominion and PJM are preparing for tighter electricity reserves due to growing demand and the retirement of older power plants, prompting investments in renewable energy and grid upgrades to meet future needs. Energy in the commonwealth is in high demanded and competition for load is high this will be a big limiting factor for AAM adoption. Developing mitigation strategies is essential to keep up with energy demands as the technology evolves. Strategies could include fleet management systems to regulate the number of vehicles charging at one time, utilizing the grid at low-demand hours and on-site energy storage.
- **On-Site Energy Production:** Some vertiports may incorporate on-site energy production, using solar panels, wind turbines, or other renewable energy sources to generate electricity for charging eVTOLs. This approach not only supports sustainability goals but also reduces reliance on the grid, making operations more resilient in the event of power outages. With the energy demands on the grid being so excessive due to high energy demands from data centers onsite generation could be a good alternative source for charging capacity.
- **Standardization:** To ensure compatibility across different types of eVTOLs and vertiports, there is a need for standardized charging systems and protocols. Stakeholders should work together to develop these standards, which will be critical for the widespread adoption of AAM

Air Traffic Management

Advanced air traffic management systems will eventually be essential for coordinating AAM's, particularly autonomous vehicles in urban environments where airspace is limited. These systems must be able to handle high traffic volumes while ensuring safety and efficiency. During the initial adoption they function on the existing infrastructure operating the way helicopters do but as the technology evolves and there are more vehicle's occupying the airspace, advanced management systems will become necessary to deal with the traffic volume.

- **Integration with Existing Systems:** During the initial adoption of AAM these vehicles will function on the existing infrastructure operating the same way helicopters do. Helicopters operate in air traffic spaces under regulations dependent on the type of airspace they are in. In controlled airspaces, they follow Air Traffic Control (ATC) instructions for altitude and separation from other aircraft, while in uncontrolled spaces, pilots must adhere to visual flight rules and avoid obstacles. Their unique abilities, such as hovering and vertical takeoff, often result in special clearances and routes, especially in urban areas. This operational flexibility, combined with noise abatement protocols, enables helicopters to maneuver effectively in congested urban environments. The initial adoption of AAM, particularly with electric Vertical Takeoff and Landing (eVTOL) vehicles, is expected to mirror helicopter operations. Like helicopters, eVTOLs will require specific air traffic routes, especially in urban settings, and special ATC clearances for vertical takeoff and landing. Both technologies rely on low-altitude airspace management and will face similar challenges regarding noise regulations and airspace integration.[5]
- **The Future of Air Traffic Management:** Advanced Air Traffic Management systems for AAM's will integrate Unmanned Traffic Management (UTM) to coordinate crewed and uncrewed aircraft, ensuring safe separation in urban areas. These systems will dynamically manage air corridors, adjusting based on traffic density, weather, and operational needs, using digital twin simulations for efficiency. Robust data-sharing frameworks will be essential, enabling real-time communication between AAM vehicles, vertiports, and traditional air traffic control, with networks like 5G enhancing situational awareness. As AAM expands, ATM systems must scale to handle increased traffic and adapt to new vehicle types and operational demands.[30]



The new ConOps document from Boeing and Wisk [31] provides a detailed roadmap for the adoption of an urban air mobility ecosystem. (Credit: Boeing)

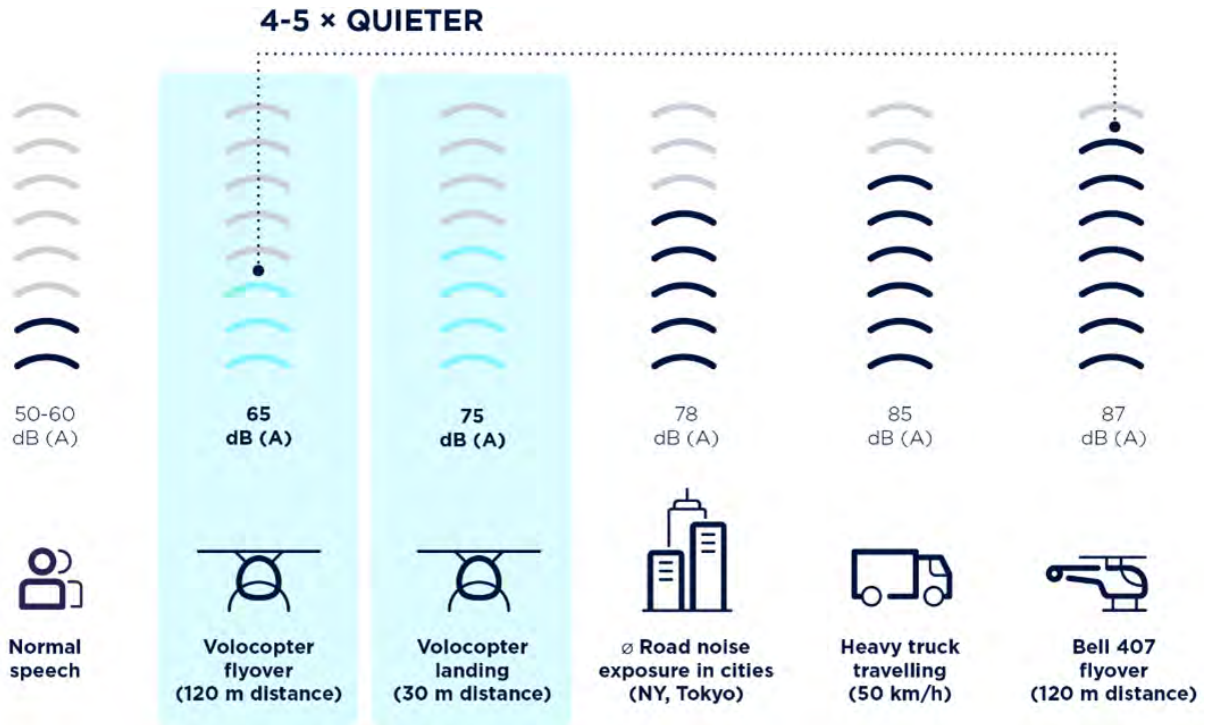
Community Integration and Public Acceptance

For AAM to succeed, it must be accepted by the communities it serves. Public acceptance will depend on several factors, including noise levels, safety, environmental impact, and the perceived benefits of AAM.

Noise Management

Noise is one of the primary concerns associated with AAM, particularly in urban areas. eVTOLs are designed to be quieter than traditional helicopters, but they still produce noise that can be disruptive, especially if operations are frequent.

- **Design Considerations:** Manufacturers are exploring various design solutions to minimize noise, such as using multiple smaller rotors, optimizing rotor placement, and developing noise-canceling technologies. Noise management should be a key consideration in the design and placement of vertiports, particularly in densely populated areas. eVTOL vehicles are much quieter than traditional VTOL vehicles like helicopters, up to 5 times quieter when in operation, making them more viable for utilization in Urban environments.[32]
- **Operational Strategies:** In addition to design solutions, operational strategies such as limiting flight times, using specific flight paths, and implementing noise abatement procedures can help mitigate the impact of AAM noise on communities.



VoloCity noise signature as compared to other urban sounds, Volocopter

Safety Concerns

Safety is another critical factor in public acceptance of AAM. Given the novelty of the technology, there may be concerns about the reliability of eVTOLs, the safety of automated flight systems, and the risk of accidents.

- **Regulatory Oversight:** Ensuring the safety of AAM operations will require rigorous regulatory oversight. Agencies like the FAA and EASA are developing certification processes and operational standards to ensure that AAM vehicles meet the highest safety standards before they are allowed to operate commercially.
- **Public Engagement:** Engaging with the public and educating them about the safety measures in place can help alleviate concerns and build trust in AAM. This can include public demonstrations, transparent communication about safety protocols, and involving communities in the planning process.

Updated photos of the Hindenburg disaster

Challenges and Opportunities for AAM

While AAM offers numerous benefits, it also presents several challenges that must be addressed to realize its full potential. These challenges include:

Infrastructure Development:

- Developing the necessary infrastructure for AAM, including vertiports, charging stations, and air traffic management systems, requires significant investment and coordination. States and local governments will need to work closely with federal agencies and private industry to ensure that infrastructure development keeps pace with technological advancements.

Regulatory Frameworks:

- Developing comprehensive regulatory frameworks is one of the biggest challenges facing AAM. These frameworks must cover a wide range of issues, including vehicle certification, airspace management, safety standards, and environmental impact. Federal agencies like the FAA and EASA are leading efforts to create these regulations, but coordination with state and local governments is also critical.
- The regulatory landscape must be flexible enough to adapt to rapidly evolving technologies while ensuring that safety and public confidence are not compromised. As new types of vehicles and operational models are developed, regulatory bodies will need to be agile and responsive to these changes.

Economic Impact:

- AAM has the potential to significantly impact the economy by creating new industries, jobs, and business opportunities. The development and operation of AAM services will require a wide range of skills and expertise, from engineering and manufacturing to air traffic management and customer service. AAM will create over 17,000 new full-time jobs. [4]
- AAM can stimulate regional economies by improving connectivity, particularly in remote or underserved areas. Virginia is projected to generate $16 billion in new business activity. It'd also boost the aerospace sector's growth by 10%, and produce $2.8 billion in local, state, and federal tax revenues. By making it easier to transport goods and people, AAM can help attract businesses and tourists to these regions, boosting local economies.[4]
- However, the economic benefits of AAM will depend on how effectively it is integrated into existing transportation systems. Poorly planned or poorly executed AAM services could lead to inefficiencies, wasted resources, and missed opportunities.

Community Engagement:

- Successful implementation of AAM requires strong community engagement. Public acceptance will be crucial for the widespread adoption of AAM, particularly in urban areas where concerns about noise, safety, and visual impact are likely to be most pronounced.
- The NASA Rotary Conference presentation emphasizes the importance of involving communities in the planning process from the outset. This includes educating the public about the benefits of AAM, addressing their concerns, and ensuring that they have a voice in decisions about where and how AAM services are implemented.
- Community engagement is also important for ensuring that AAM services are accessible and equitable. Efforts should be made to ensure that AAM does not exacerbate existing inequalities or create new ones by focusing only on affluent areas or those with existing transportation infrastructure.

Lessons from International AAM Initiatives

As the United States prepares for the implementation of AAM, there are valuable lessons to be learned from international initiatives. Several countries are already making significant strides in AAM, and their experiences can provide insights into best practices and potential pitfalls.

Europe:

Germany:

- Germany is home to several leading AAM companies, including Volocopter and Lilium, both of which are actively testing their vehicles and working towards certification. Germany's approach to AAM is characterized by strong collaboration between industry, government, and academia, with a focus on developing the necessary infrastructure and regulatory frameworks to support widespread adoption.
- The German government has also been proactive in engaging with the public and ensuring that AAM services are integrated into broader transportation networks. This holistic approach ensures that AAM is not seen as a standalone technology but as part of a broader strategy to improve mobility and sustainability. [33]

United Kingdom:

- The United Kingdom is another key player in the AAM space, with a focus on developing UAM services in major cities like London. The UK government has established the Future Flight Challenge, a program that provides funding and support for AAM projects, including the development of new technologies, infrastructure, and business models.
- The UK's approach to AAM emphasizes the importance of public engagement and community integration. The government has launched several initiatives to educate the public about AAM and involve them in the planning process. This has helped build public confidence and support for AAM, paving the way for future deployments. [34]

Asia:

China:

- China is rapidly emerging as a leader in AAM, with significant investments in both technology development and infrastructure. Companies like EHang are at the forefront of this effort, testing autonomous aerial vehicles (AAVs) for use in urban air mobility, cargo transport, and emergency response.
- The Chinese government has taken a proactive approach to AAM, working closely with companies to develop regulatory frameworks and support the construction of vertiports and other infrastructure. China's focus on rapid deployment and large-scale adoption could serve as a model for other countries looking to accelerate their own AAM initiatives. [35]

Japan:

- Japan is exploring the use of AAM for both urban air mobility and regional connectivity. The Japanese government has partnered with industry leaders to conduct pilot projects and develop the necessary infrastructure and regulations. Japan's approach to AAM is characterized by a strong emphasis on safety, with rigorous testing and certification processes in place to ensure that vehicles meet the highest standards.
- Japan is also focusing on integrating AAM with existing transportation systems, such as rail and road networks, to create a seamless and efficient mobility ecosystem. This integrated approach ensures that AAM complements rather than competes with other modes of transportation, maximizing its benefits for society. [36]

Implications for the Commonwealth of Virginia

The experiences of other states and countries provide valuable lessons for Virginia as it prepares for the onset of AAM. By learning from these initiatives, Virginia can develop a comprehensive strategy that addresses the unique challenges and opportunities presented by AAM.

Leveraging Existing Infrastructure:

- Virginia is well-positioned to take advantage of existing infrastructure, such as airports, highways, and public transportation systems, to support AAM. By incentivizing the repurposing of and upgrading of these facilities, the state can incentivize the development a robust AAM network that connects urban, suburban, and rural areas.
- Virginia should focus on integrating AAM with existing transportation systems to create a seamless mobility experience for users. This could include developing multimodal hubs that connect AAM services with buses, trains, and other forms of transportation.

Supporting Innovation and Research:

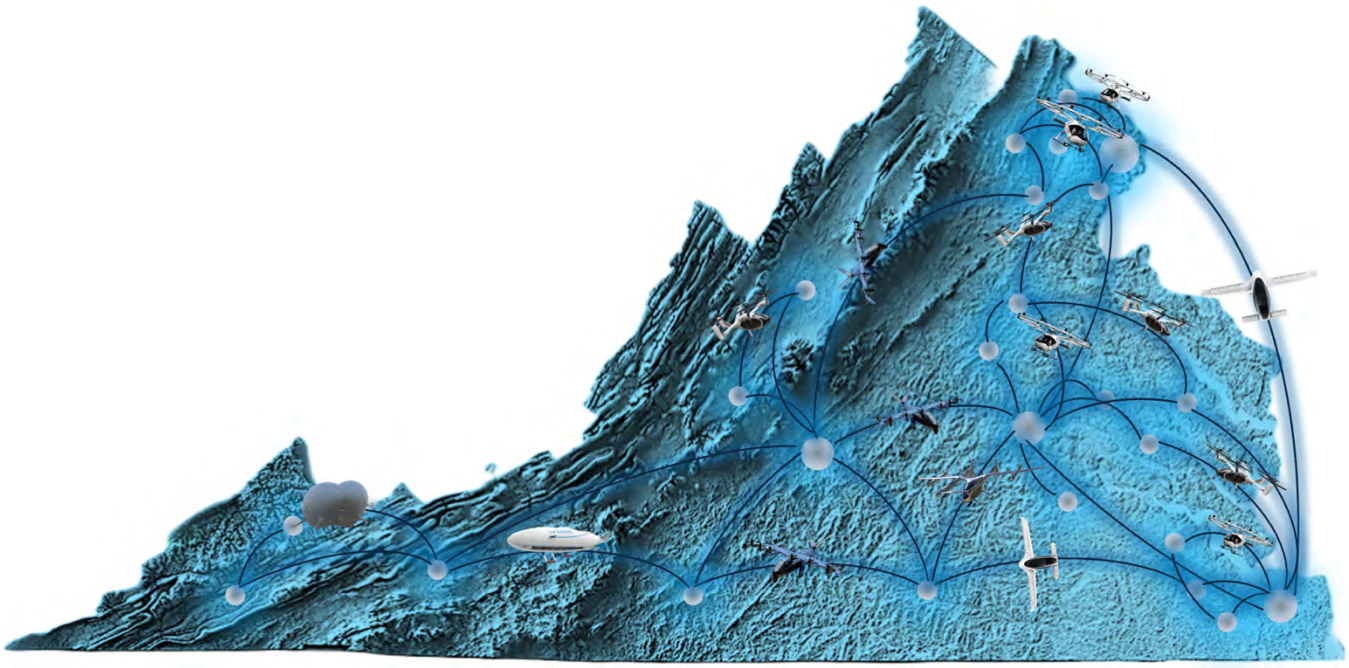
- Virginia's strong academic and research institutions, such as Virginia Tech and the University of Virginia, provide a solid foundation for innovation in AAM. The state should leverage these resources to conduct research on AAM technologies, develop new business models, and explore the social and environmental impacts of AAM.
- By incentivizing investing, research and development, Virginia can position itself as a leader in AAM, attracting businesses and creating high-quality jobs in the process. This will not only benefit the state's economy but also contribute to the broader goal of making AAM a reality across the United States.

Engaging with Communities:

- Public engagement will be crucial for the successful adoption of AAM in Virginia. The state should prioritize efforts to educate the public about the benefits of AAM, address their concerns, and involve them in the planning process. This could include holding public forums, conducting surveys, and working with local communities to identify potential vertiport locations.
- The experiences of other states and countries show that community engagement is key to building public trust and support for AAM. By taking a proactive approach to engagement, Virginia can ensure that AAM services are welcomed by communities and integrated into the fabric of everyday life.

Conclusion

Advanced Air Mobility represents a transformative opportunity for the Commonwealth of Virginia. By learning from the experiences of other states and countries, investing in infrastructure and research, and engaging with communities, Virginia can position itself as a leader in this emerging field. The successful implementation of AAM will not only improve mobility and connectivity within the state but also create new economic opportunities and enhance the quality of life for all Virginians. Advanced Air Mobility represents a significant shift in how we think about transportation, offering new solutions for urban congestion, regional connectivity, and emergency response. By facilitating and collaborating with stakeholders in investing in the necessary infrastructure, regulations, and public engagement, the Commonwealth of Virginia can position itself as a leader in this emerging field, reaping the economic, social, and environmental benefits of this new era of mobility.



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Recommendations for Realizing the Benefits of Advanced Air Mobility in the Commonwealth of Virginia

A report from the Regional Air Mobility/Urban Air Mobility Committee of the
Virginia Advanced Air Mobility Alliance (VAAMA) for the
Virginia Innovation Partnership Corporation and Virginia Department of Aviation

April 5, 2023

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RAM/UAM Committee Members

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Executive Summary

Advanced Aerial Mobility (AAM) is a nascent and rapidly emerging new concept of air transportation that moves people and cargo between places not conveniently served by surface transportation or underserved by aviation—local, regional, intraregional, urban—using revolutionary new aircraft that are only just now becoming possible.

The Virginia Innovation Partnership Corporation (VIPC) and the Virginia Department of Aviation (DOAV) jointly established the Virginia Advanced Air Mobility Alliance (VAAMA) to bring industry, academia, and state/tribal/federal government voices together to develop recommendations for positioning the Commonwealth to benefit from AAM. VIPC established this RAM/UAM Committee to focus on the Regional Air Mobility (RAM) and Urban Air Mobility (UAM) market segments, typified by a new generation of hybrid-electric and fully electric aircraft now undergoing FAA certification and able to carry passengers and cargo more economically, and with vastly lower noise and emissions, than was previously possible. Another VAAMA committee was established to focus on Low Altitude Mobility, typified by the many small UAS public safety and small package delivery missions generally carried out at short ranges and below 400 feet above ground level but also including larger UAS operating at low altitude in airspace typically not served by Air Traffic Control. The markets share some common challenges yet differ considerably in the size of the vehicles, operations in the national airspace system vs the lower altitude UAS Traffic Management environment, operations at airports and heliports, energy distribution, certification standards, public perception, and other factors.

The RAM/UAM Committee included two vehicle manufacturers, NASA, MITRE, airports, tribal government leaders, digital infrastructure service providers, energy companies, universities, and others.

The Committee finds that initial entry into service of these advanced aircraft is feasible mid-decade and that the infrastructure policy, and operational needs vary somewhat with the mission (RAM/UAM). Service will begin with piloted vehicles operating largely from existing facilities in the air traffic environment as it exists today, providing near term opportunities to attract operators, enhance mobility in Virginia, and begin development of the policies and infrastructure required for optionally piloted and remotely piloted operations to begin around the end of the decade. Digital and physical Infrastructure, policy, regulatory, energy distribution and other needs evolve as the industry matures, scales, and introduces greater automation in later years.

The committee recommends a commonwealth strategy of enabling the nascent industry entry into revenue services this decade while establishing the environment to accommodate the later scaling and increased automation of this transportation mode as well as integrating AAM into Virginia land use and transportation planning. The single greatest immediate need is senior leadership at appropriate levels, ideally within the Office of the Secretary of Transportation, to manage the complexity and decision points required, coordinate across multiple Commonwealth agencies, as well as coordination of legislative asks and representation to industry and Federal policy makers at national levels. Given the need to integrate AAM into intermodal transportation planning,

Commonwealth transportation planning, and to develop infrastructure, the need to begin the leadership is now. The full set of recommendations are:

- Adopt an overarching strategy to focus on the needs of the nascent AAM sector today while creating the conditions to support a more mature market.
- Quickly establish senior executive leadership and resources to coordinate state initiatives, manage a system engineering process and decision points, and engage city and state land use and transportation planners.
- Ensure an AAM-supportive policy and regulatory environment.
- Respect the unique aspects and concepts of operation of each major AAM mission category (RAM or UAM), and the phased needs of these market segments in developing relevant policy, initiatives, and infrastructure.
- Adopt a strategy of advancing RAM and UAM by facilitating a series of operational demonstrations and trials to tackle major challenges.
- Develop an environment to facilitate operational demos, early revenue trials, and development of beyond visual line of sight, concepts, technologies, and standards.
- Leverage partnerships with neighboring states to leverage resources and harmonize policy, operational environments, and infrastructure.
- Perform an assessment of Virginia public use airports to assess advanced air mobility demand and infrastructure needs. Consider leveraging Virginia Small Aircraft Transportation System Corporation (VSATS) capabilities to support this assessment.
- In alignment with assessed AAM demand, perform physical and/or digital infrastructure improvements at select Virginia airports to accommodate.
- Consider potential dual use concepts and technologies and infrastructure for the civil RAM mission and DOD cargo logistics requirements to potentially leverage investments being made to support DOD.
- Consider the infrastructure and policy environment needed to attract RAM and UAM operations centers to Virginia airports.
- Collaborate with the industry and the FAA to define fleet high-density procedures for Virginia's public use airports.
- Assess the potential for leveraging sUAS technology, infrastructure, and operational capabilities in Virginia, as a basis for attracting RAM and UAM.

Simultaneous with the deliberations of the RAM/UAM Committee the VIPC commissioned NEXA Advisors to develop an economic benefits analysis for the Commonwealth[1]. The recommendations significantly parallel those of the RAM/UAM Committee and the economic benefits of fostering AAM were shown to be significant. To quote the NEXA report:

"A new form of mobility will soon transform the lives of Virginia residents, businesses, educators, agencies, and public safety personnel…… Within a few years, passengers will take short, quiet, carbon-free flights within cities and suburbs, and between rural airports and urban centers. They will also fly between city pairs and rural airports at awkward distances currently not served by airlines, hopping on quick flights from Winchester, Blacksburg, Charlottesville, and Chesapeake to places like Washington Dulles Airport, the Capitol at Richmond, or downtown Washington, DC.

According to our findings the economic impact and benefits to the Commonwealth of Virginia by the AAM industry (through 2045) will:

- *Generate $16 billion in new business activity and related stimulus, in part by integrating AAM vehicle and related manufacturing into the state.*
- *Add 10% or more to the growth of Virginia's existing aerospace sector.*
- *Produce $2.8 billion in local, state, and federal tax revenues.*
- *Create over 17,000 new full-time aerospace industry and other jobs in the Commonwealth.*
- *Bring employment and educational opportunities to all regions of the Commonwealth. including underserved and economically challenged areas. "*

Virginia can build on its extensive history in aviation and aerospace, and work to apply the lessons in economic motivations to support the deployment of AAM transportation systems innovations in the Commonwealth. Undertaking a program that coordinates public and private investments will require strong and collaborative leadership from all levels in Virginia's Administration and from the industry partners who see the state as a viable place for them in this new industry. These investments must produce compelling system demonstrations, proofs of concepts, and development of state and local related policy and regulatory matters.

[1] "Virginia's Advanced Air Mobility Future, AAM's economic benefit for the Commonwealth", NEXA Advisors & UAM Geomatics, Inc., January 2023. Sponsored by the Virginia Innovation Partnership Corporation (VIPC) and the Office of the Secretary of Commerce and Trade.

Precis: Why Advanced Air Mobility – Why in Virginia?

America's history of mobility systems innovations dates back to the Transcontinental Railroad of 1869, to the invention of air travel in the 1920's, and to the Interstate Highway system of the 1950's, among others. These systems propelled our nation's economic progress over the past century and more. In the seminal book on economics, "An Inquiry into the Nature and Causes of the Wealth of Nations (Smith, 1776)," Adam Smith explains the enduring implications of economic forces such as "Production and Exchange" and labor force productivity as the drivers for national wealth, quality of life, and economic opportunity. These implications include the role of physically connecting production with upstream supply chains and with downstream consumption, as well as delivering goods and services, and connecting people and ideas. Our nation's mobility innovations have propelled our economic growth and productivity over decades by enabling transportation of people and cargo by air, roads, rail, and water, to and from many, but far from all useful origins and destinations. Over recent years, many communities and industries served by these modes have become increasingly challenged by highway congestion, reduced or non-existent air services, or limited rail and bus options. The point is that when markets are connected, whether by highway, rail, digital communications, or by air, the benefits flow into societal qualities of life, standards of living, and productivity. The Commonwealth of Virginia is well positioned to capitalize on the economic drivers that would be amplified through Advanced Air Mobility (AAM) innovations hosted by the state, as well as advance aviation transportation sustainability offered in the transition to the advanced energy systems employed in AAM.

A positive correlation is likely between Gross Domestic Product per capita and the availability of air and ground transportation system services between and within U.S. states. States with more invested in transportation and communication infrastructure and services likely have higher GDP per capita. On the other hand, states with less transportation infrastructure and services likely have lower GDP per capita. However, it is important to note that there are many other factors that could also influence the availability of transportation services in a state, such as the size and geography of the state, population density, and the overall demand for transportation services. Regardless of these factors, greater productivity is likely in any state that invests in connecting people and places through innovations such as AAM systems. Just as the Internet leveraged digital connectivity through "smart" nodes (i.e., computers and mobile devices) to create exponential growth for the largest companies (by market cap) in the world today, a network of "smart" air mobility nodes (e.g., places of commerce) can foster accelerated economic outcomes independent of airline airports, rail stations, and Interstate Highways.

Virginia owns a long history in aviation and aerospace innovations, including the following:

1. The first Wright Flyer built for the Army was delivered to Fort Myer, Virginia by Orville Wright in 1908.
2. The first airplane takeoff from a battleship, in Hampton Roads, Virginia in 1910.
3. The first aeronautics research facility, establishing the National Advisory Committee for Aeronautics (NACA) in 1915.
4. The first aviator to fly over both poles, Adm. Richard E. Byrd of Virginia, in 1926.

5. Development and testing of technologies for the Bell X-1, the first supersonic aircraft, in wind tunnels at NACA Langley Memorial Aeronautical Laboratory in Hampton, Virginia, 1940's.
6. The first state to implement AWOS-3 weather observing stations, for all public-use airports in the commonwealth, connected to the FAA National Airspace Data Interchange Network (NADIN), enabling safer operations; a project supported by the Department of Aviation-affiliated VA Small Aircraft Transportation System (VSATS) corporation, in the 1990's.
7. The first state to implement satellite navigation-based instrument approach procedures, enabling more commerce and safer operations for all 66 public-use airports; project supported by the Department of Aviation-affiliated VA Small Aircraft Transportation System (VSATS) corporation, beginning in the 2000's.
8. The first state to complete qualification testing with the FAA for a remote tower system, enabling lower cost, enhanced safety services at airports without physical control towers, in partnership with the FAA and Saab-Sensis; a project supported by the Department of Aviation-affiliated VA Small Aircraft Transportation System (VSATS) corporation, in the 2000's.
9. The first state-based commercial/government/private space facility launches, from the Mid-Atlantic Regional Spaceport built at NASA Wallops Flight Facility (one of the oldest launch sites in the world), including flights to supply the International Space Station, lunar missions, and satellites; beginning in 2013.
10. NASA Langley Research Center-led programs and projects laid many of the technical foundations for the newly emerging Advanced Air Mobility vehicle and operating concepts for regional and urban transportation in technologically advanced, electric-propelled, autonomous, piloted, and remotely piloted Vertical and Short-Conventional (eVTOL and eCSTOL) aircraft being developed around the globe, including in Virginia. Projects included the Advanced General Aviation Transportation Experiments (AGATE)[2]; Aviation Safety Program (AvSP)[3] Synthetic Vision technology; Small Aircraft Transportation System (SATS)[4]; X-57 Maxwell research aircraft[5]; and the Center for High-Efficiency Electrical Technologies for Aircraft (CHEETA)[6]; among other projects, as well as contributions from other NASA Aeronautics Research Centers in California and Ohio. These research activities began in the 1980's and continue to the present.

Fast forward to our present time and consider how Virginia can build on its extensive history in aviation and aerospace, and work to apply the lessons in economic motivations to support the deployment of AAM transportation systems innovations in the Commonwealth. Undertaking a program that coordinates public and private investments will require strong and collaborative leadership from all levels in Virginia's Administration and from the industry partners who see the state as a viable place for them in this new industry. These investments must produce compelling system demonstrations, proofs of concepts, and development of state and local related policy and regulatory matters.

[2] https://www.nasa.gov/centers/langley/news/factsheets/AGATE.html
[3] https://www.nasa.gov/centers/langley/news/factsheets/SynthVision.html
[4] https://www.nasa.gov/centers/langley/news/factsheets/SATS.html
[5] https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-109.html
[6] https://www.nasa.gov/aeroresearch/university-researchers-moving-electrified-aviation-forward-with-nasa

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Introduction

A convergence of technologies, coupled with emergence of demands, are driving global investments in development of an entirely new class of aircraft and of transportation system concepts for passengers, cargo, and services. The emergent effect is to enable what NASA defines as Advanced Air Mobility:

> "Advanced Air Mobility is a new concept of air transportation that moves people and cargo between places not conveniently served by surface transportation or underserved by aviation—local, regional, intraregional, urban—using revolutionary new aircraft that are only just now becoming possible."

The AAM missions and Large and Small UAS vehicles descriptions are provided later in this report.

The aircraft and related technologies include the following:

- Electric propulsion for more sustainable energy
- Fly-by-wire systems that simplify the piloting task and training required
- Digital wireless connectivity for command and control, digital voice to ATC, and related operational services for UAVs

- Airspace management services
- Digital Twin systems for improvements in prognostic maintenance for fleets of aircraft
- Advanced composite manufacturing for lower cost and greater scalability in production systems
- Automation and increasing use of autonomous systems to enable simplified vehicle operations (SVO) for onboard and remote pilots, and eventually remotely supervised "autonomous" aircraft.

The demand drivers include the following:

- Job creation (e.g. aerospace engineers, technicians, communications engineers, flight operations coordinators, aircraft maintenance, software engineers, navigation and surveillance engineers and technicians, permitting and construction personnel for airport, vertiport and communications infrastructure, passenger hospitality)
- Mobility solutions for people and cargo in underserved communities and in congested areas
- Emergency and medical services
- Public safety
- Agriculture
- Infrastructure inspection and maintenance
- Disaster relief
- Military services mission support
- AAM-related STEM and workforce development

The Virginia Innovation Partnership Corporation (VIPC) and the Virginia Department of Aviation (DOAV) are co-leading the Virginia Advanced Air Mobility Alliance (VAAMA). The VAAMA purpose is to develop a framework for the advancement of commercial and government AAM services in the Commonwealth and to make recommendations to the Commonwealth on what the state can do to position itself as a leader in AAM. The VAAMA is considering technology needs, policy issues, infrastructure, community engagement, and other factors related to the adoption of AAM across the many missions ranging from small package delivery to Urban and Regional Air Mobility.

In support of VAAMA and VIPC/DOAV, a committee was formed to focus on Regional Air Mobility (RAM) and Urban Air Mobility (UAM). The scope of this RAM/UAM Committee addresses recommendations for hastening the early entry into service of the emerging transportation capabilities of AAM. The committee scope does not include economic development avenues that are addressed elsewhere by VIPC or other Virginia organizations, such as attraction of manufacturing facilities, workforce development, and development of entrepreneurial startup ecosystems. However, the committee agreed to stress the importance of skilled workforce and the need for increased workforce development for AAM, the unmanned systems industry, and the aerospace industry writ large. Also, recommendations by this committee do not address requirements for low altitude missions such as small package delivery, typically flown by small UAS (S-UAS). These missions are the focus of a peer VAAMA committee titled Low Altitude Mobility (LAM). The focus of the RAM/UAM Committee is on transportation of cargo and passengers by

Large-UAS (L-UAS) and advanced aircraft just now being developed by industry (e.g.; eVTOL, hybrid-electric eSTOL) that will be piloted at entry-into-service and for some years to come.

The purpose of this paper is to provide a summary of the RAM/UAM opportunity landscape and to propose a framework and specific recommendations for adoption by the Commonwealth of Virginia. The framework and recommendations address compelling system demonstrations, proofs of concepts, development of related state and local policy, regulatory, and infrastructure matters.

The Innovation S-Curve and Implications for AAM in Virginia

The concept of the innovation life cycle and its portrayal in a market adoption S-curve[7, 8] illuminates the timing, risks, and uncertainties in the evolution of AAM in the marketplace, and in developing response roadmaps. The S-curve plots a metric of cumulative market penetration of an innovation as a percent of the addressable market (on the ordinate), against the timeline for the innovation to reach full market penetration (on the abscissa). In general, the curve has three phases:

1. Early Adopter Phase. This phase is characterized by a relatively flat slope at the left as the innovation is in its early entry into service, following certifications and related infrastructure build-out. This phase is characterized by low rate manufacturing, market trials, high costs to consumers, and slow adoption. Entrepreneurship, market segmentation, and invention dominate in this phase.
2. Core Growth (Acceleration) Phase. This phase is characterized by the initial upturn in market adoption. The dominant vehicle designs or and business operating system architectures emerge. The innovation begins to become more generally useful. A relatively steep slope of market adoption occurs as use-cases proliferate. Vertical integration, conservatism, and quality management evolve during this phase. Importantly, during this phase the inflection point (where the second derivative of the curve passes from positive to negative) indicates the point at which the rate of change of market penetration begins to decelerate. Knowing where this inflection may occur provides vital strategic information for participants in both the public and private sectors response roadmaps.
3. Maturity Phase. This phase is characterized by a relatively flat technology maturation phase in which progress comes in shorter and more incremental product change cycle times that are more costly to achieve. Process management and improvement, bureaucratization, cost-cutting, slowed market growth, economy of scale reducing product costs occur in this phase.

The RAM and UAM aspect of AAM are currently in the early phase of the S-curve (Figure 1). Many firms are developing RAM/UAM passenger and cargo vehicles, and a few are approaching initial certification, perhaps as early as 2024. However, most of these vehicles have not yet achieved

[7] Christensen, *The Innovator's Dilemma*, 1997
[8] Modis, *Conquering Uncertainty*, 1996

FAA certification; operating infrastructure including airspace procedures for some is yet to be deployed; passenger operations have not yet begun; community acceptance and business models have not yet been validated; regulations for flight operations are not yet proposed, and numerous standards have yet to be defined. All of these topics represent key elements of a project plan for the state efforts to support this industrial development.

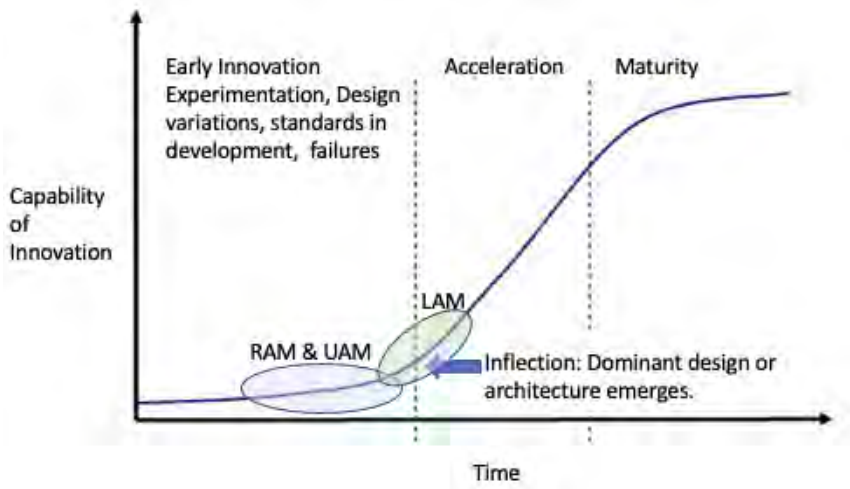

Figure 1 – Innovation S-curve

Low Altitude Mobility (LAM) missions (including small UAS package delivery) are arguably more mature and crossing into the early core growth phase. Regulations now exist for pilot licensing and for commercial operations (Part 107), approvals have been granted for small UAS to perform air carrier operations (Part 135), and commercial and public safety operations are now being flown. However, scale up of the LAM mission is still severely limited by various factors, chief of which are the standards and protocols for Beyond Visual Line of Sight (BVLOS) operations. It is worth noting that addressing operational and infrastructure challenges in one domain (LAM/RAM/UAM) may also yield benefits for the other domains. See Appendix C for a discussion of linkages between these missions.

We observe that the S-curve transition from the Early Adopter to the Core Growth phase for RAM and UAM will occur when:

1. The initial vehicles have achieved FAA certification and authorization to operate commercially.
2. Adequate infrastructure is deployed in at least one location needed for initial demonstration and revenue flights. Passenger acceptance and initial business model validation has taken place via passenger carrying revenue flights. Validation of end to end ConOps, protocols, and interfaces with digital and physical infrastructure has satisfied investors, regulators, and customers.
3. Relevant standards and requirements have been defined for the subset of operations requiring Detect and Avoid (DAA) for BVLOS operations.

Committee Process and Framework

These recommendations are developed by the RAM/UAM Committee of the VAAMA. The effort began by analyzing strategic reports prepared for the states of Ohio, New Jersey, Texas, and

Arkansas by Crown Consulting, NEXA Capital, and Deloitte Consulting. Collectively these reports represented significant industry intelligence and intellectual effort to discern appropriate state strategies for AAM. The committee then employed a top-down approach to define a plausible industry timeline for vehicle certification and entry into service (EIS), then the associated concepts of operation, then the associated time-phased implications for infrastructure and policy. Finally, given the expected timelines, ConOps, and infrastructure needs, a set of findings and recommendations are developed for consideration by the VIPC and DOAV as they develop their plans and support for the 2023 Virginia legislative session (using this report in draft form) and later use by VIPC and DOAV for strategic plan development, guiding feasibility studies and early investments, and preparation for the 2024 legislative session.

The framework developed for this work brings two important attributes to the discussion; (1) a strategic framework that begins with a survey of the external environment, establishes a goal, and employs a top-down decomposition of relevant ConOps, industry needs, and implications for infrastructure and state actions and (2) introduces a two-dimensional framework of the AAM mission types and the time phasing of their evolution. As such, this represents the early stage of a strategic planning process and system engineering approach. Recommendations will be made for follow-through of this process.

A series of meetings were held with the RAM/UAM Committee to share information and agree on process, review progress, and gain feedback and support for the recommendations. As required, meetings with individual team members were held to aid inclusion where schedules did not permit gaining full participation in the plenary meetings. The views of AAM OEMS and operators are critical, so dedicated discussions were held with Electra.Aero, Joby Aviation, and Xwing.

- November 2 and 8, 2022: A kickoff meeting and review of state reports was held. The committee agreed on a time phased approach, the need to develop a plausible timeline, and outreach to firms not in the core team. Two meetings were held to accommodate the schedules of as many members as possible.
- December 15, 2022: Review of the timelines and implied ConOps and infrastructure needs.
- January 31, 2023: Review this report, findings, and recommendations and provide edits.

Missions of Interest

This work will adopt the language of describing “missions” and “aircraft” for clarity. This language is evolving within FAA and NASA as mission description and aircraft types have often been mixed in discussion with language such as “UAS and AAM”. As will be illustrated below many operations concepts and requirements flow from the mission type and whether the aircraft is piloted or optionally piloted/autonomous.

- UAS and other, piloted AAM vehicles are the aircraft, versus the missions, and related operational systems enabling controlled flight. While the DoD has five UAS classes, there appear to be two general classes of UAS relevant to AAM: small (S-UAS) and large (L-UAS). Both small and large UAS can be used for a wide range of missions. Small UAS are limited to 55 lb. gross weight, are piloted remotely or autonomously, most often below 400 feet AGL, with UTM services. For the purposes of this paper, large UAS may

range from 100s of pounds gross weight to (typically) 5000 to 7000 pounds and may be optionally piloted or remotely piloted, primarily above 400 feet AGL, with PSU, legacy ATC, and C2CSP services, as needed. Likewise, eVTOL and electric propulsion fixed wing vehicles are AAM aircraft that may be employed in a variety of missions and may be piloted, optionally piloted or autonomous. In some cases, aircraft that are piloted and that we would not consider to be UAS will become L-UAS, and will be flying the same missions, once the autonomy matures to the point that the aircraft may be operated without crew on board.

- AAM comprises the missions, versus the aircraft, and the related components of the ecosystem enabling those missions. The NASA proposed taxonomy[9] for these missions (referred to as "application categories" because there are many specific potential missions within each of these categories) is as follows:
  - UAM is "*a safe, efficient, convenient, affordable, and accessible air transportation system for passengers and cargo...around metropolitan areas*"
  - RAM is another part of AAM that "*focuses on building upon existing airport infrastructure to transport people and goods using innovative aircraft that offer a huge improvement in efficiency, affordability, and community-friendly integration over existing regional transportation options*".
  - "*LAM is a newly proposed term for very low-altitude operations that principally occur within the Unmanned Aircraft System (UAS) Traffic Management (UTM) environment. Many refer to LAM as small UAS (sUAS) operations, which are operations of aircraft that weigh less than 55 lb., but the FAA's UTM Concept of Operations version 2.0 does not limit larger UAS (i.e., those above 55 lb.) from utilizing UTM; furthermore, the LAM term provides parallelism with UAM and RAM, focusing on the key attribute of these missions: flying entirely at lower altitudes than historical aviation—typically under 400 ft above ground level*."

The framework in use in this paper (2-D construct of missions and time) is useful as the differences between these domains include certification standards; economic benefits; land-side infrastructure requirements; airspace services requirements; operator training and certification standards; command and control spectrum and requirements; communications, navigation, and surveillance systems requirements; aeronautical information needs; and different cultures of the domains. Systems developed for the S-UAS industry may partially meet the infrastructure, economic, regulatory, policy, Comm/Nav/Surveillance needs, and airspace procedures required for L-UAS. However, they will almost certainly not satisfy all of the RAM and UAM requirements. Additional analysis of RAM/UAM concepts of operation, requirements, and system capabilities are needed. Therefore, this report maintains a separation in the definition of requirements and recommendations between the two domains and focuses on the RAM and UAM missions.

The missions to be treated in this paper are:

- UAM: Urban Air Mobility typically using eVTOL aircraft that are just now approaching FAA certification, some of which may be certified in 2024 or 2025. The vast majority of these missions are expected to be operated with pilots on board at Entry Into Service (EIS) and

[9] "A Proposed Taxonomy for Advanced Air Mobility", (https://ntrs.nasa.gov/citations/20220006225)

for some time, until remote pilot or autonomous operations are feasible. Examples of vehicles in development for UAM missions include those from Joby, Archer, Wisk, and others.

- RAM: Two subtypes of Regional Air Mobility are treated. The purpose of defining mission types is based on the need to define the operational environment for the missions (airspace, ATC interactions, airports) and flow down concepts of operation and required infrastructure, policy, phasing of needs, and other factors. RAM is divided into two subtypes within this report as initial entry into revenue service for "RAM(L for Large)" will be with onboard pilots, while revenue service for RAM(S for Small) will take place uncrewed. As such, these mission subtypes will employ different phasing of ConOps, technical needs, and infrastructure requirements.
    - RAM(L): Regional air mobility missions flown in vehicles of sufficient size to carry a pilot and passengers or equivalent weight in cargo. These missions are enabled by aircraft such as the Electra.Aero hybrid-electric aircraft (9 passengers or 2500 lb. cargo with 400 nm range) and the BETA Technologies battery-electric CTOL/eVTOL Alia 250 (5+ 1 passengers and 250 nm range). Also included in this mission are cargo operations enabled by firms such as Xwing and Reliable Robotics, both developing the technology to allow currently certified cargo aircraft, beginning with the Cessna 208 Caravan, to be remotely operated. Ampaire, developing hybrid-electric piloted aircraft with lower noise and lower operating costs also enables expanded RAM(L) services. These aircraft types will operate primarily at first from existing airports and heliports expanding later with dedicated vertiports and "pocket airports", and using current ATC procedures in class B, C, D, E, and G airspace.
    - RAM(S): Missions enabled by L-UAS just now being certified as exemplified by the Elroy Air Chaparral (an eVTOL aerial cargo system that can autonomously pick up 300-500 pounds of cargo and deliver it by air up to 300 miles). These aircraft will be remotely operated from day 1, may operate from regional airports and off-airport logistics centers, and at altitude above the UTM domain but possibly below altitudes, especially in rural areas, where ATC communication, surveillance, separation, and flight emergency services are available (500 to 2000 feet AGL).

The LAM mission is not explored in this paper and is the subject of the VAAMA LAM Committee. The LAM missions are generally (but not exclusively) flown with small UAS below 400 feet AGL and in the UAS Traffic Management (UTM) environment and include last-mile small package delivery, first responder uses, infrastructure inspections, and more. RAM and UAM missions will be operating in the Air Traffic Management (ATM) environment and rarely operate below 400 feet other than for takeoff and landing. However, parallels will be noted in ConOps and challenges between LAM and RAM(S). Other non-transportation missions, not addressed in this paper, also stand to benefit from the same infrastructure ecosystem that will enable RAM(S). These include the emerging use of long distance capable UAS to inspect linear infrastructure (pipelines, electric power lines, rail). Firms in this space include Virginia based AATI and Florida Power & Light testing of the Navmar Applied Sciences Corporation's Teros large UAV.

Plausible Industry Timelines and Implications

Industry timelines are developed in order to estimate the current maturity of this market and of the lead time and phasing required for Commonwealth actions. The industry timeline below was developed from multiple publicly available data or statements including:

1. Industry press releases and announcements concerning certification progress and projections, pre-orders for vehicles, or plans for demos or initial entry into service.
2. Industry trade press articles involving interviews with company representatives
3. Boeing/Wisk ConOps[10]
4. FAA *UAM ConOps v1.0*, June 2020
5. UAM visions reports prepared for NASA[11] and by NASA[12]
6. SMG Consulting AAM Reality Index updates (https://aamrealityindex.com)
7. Reports prepared by Deloitte Consulting, Crown, NEXA Capital for the states of Ohio, New Jersey, Texas, Arkansas (see Bibliography)

The timelines below represent these data sources, which are largely marketing predictions and do not represent predictions by the VAAMA RAM/UAM Committee as to specific dates. While the SMG AAM Reality Index examines technology maturity and other factors to estimate the likelihood of meeting claimed EIS dates, no analysis was conducted by this RAM/UAM Committee to evaluate the claims. In general, we believe that the trends have probabilistic utility, even if EIS dates move somewhat. The inherent nature of the innovation S-curve also provides strategic context regarding understanding where the industry stands in market deployment. For example, the large number of firms developing vehicles today will inevitably be subject to the market challenges as some succeed and some fail, and some will merge, or be acquired. These individual developments should be viewed as the natural process of survival of the fittest in the marketplace. Likewise, until the new vehicle designs have actually achieved type certification, especially those with technology not previously certified, including battery electric propulsion, and higher levels of automation and autonomy, some schedules will inevitably slip to the right relative to current marketing projections. Uncertainty sources will be discussed more below.

Given these constraints, Figure 2 provides claimed Entry Into Service (EIS) dates against the backdrop of the S-curve. The timeframes labeled “enable”, “accelerate”, “scale” represent the three phases of action employed by Deloitte to their sponsors of the New Jersey study. These phases are appropriate characterizations for an S-curve dynamic, where getting to first viable operational product is the focus prior to the “Accelerate” or “Core Growth” phase. The blue ovals represent EIS dates suggested by the manufacturers (note however that Boeing/Wisk has not provided a specific EIS date but has only suggested “the safe initiation of uncrewed UAM passenger operations in the NAS by the end of this decade.”) The green ovals represent approximate EIS or trial dates by a number of operators, for example an announcement by United

[10] Boeing and Wisk, *Concept of Operations for Uncrewed Urban Air Mobility*, September 2022

[11] Deloitte Consulting, *UAM Vision Concept of Operations (ConOps) UAM Maturity Level (UML) 4 Version 1.0*, Prepared for NASA, December 2020

[12] Michael Patterson, Doug Isaacson, and Nancy Mendonca (NASA), *Intermediate State UAM Vision Concept of Operations (ConOps) Overview*, February 2021

Airlines of a target date of 2025 for initial eVTOL shuttle service operations in New York city in partnership with Archer. The blue squares represent plans for eVTOL air taxi service to be demonstrated at the Paris 2024 Olympics and at the Los Angeles 2028 Olympics.

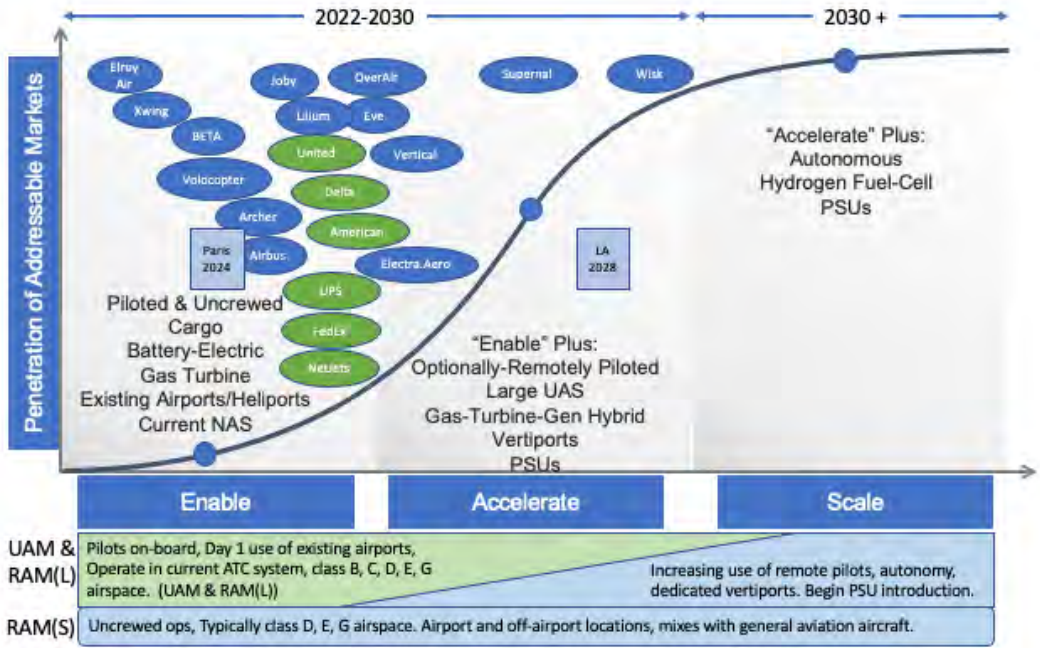

Figure 2 - Industry Plausible Timeline

The lower part of the figure provides trends in operational pilotage ConOps for these missions. UAM and RAM(L) will begin revenue operations with onboard pilots and largely or entirely, depending on the vehicle and the operation, within current airport infrastructure, airspace access, ATC procedures, and Comm/Nav/Surveillance systems. The reduced operating cost structure of these aircraft, the lower noise, and the reduced maintenance needs provide the conditions for scaling of business models and allow increased service to more communities. As the multiple challenges of certifying the systems needed for remote pilot or autonomous operations are solved, operations will begin to include uncrewed operations. For the most part the Committee members and vendors talked with do not anticipate remote pilot or autonomous operation until near the end of this decade.

RAM(S) missions on the other hand are uncrewed at all times. These missions will be flown by aircraft weighing close to 1000 lb., generally above the UTM domain but below typical enroute cruise altitudes of general aviation aircraft. As such the challenges and ConOps for BVLOS operations will likely be a mix of those that exist for sUAS flying LAM missions and the need to operate in other airspace classes and potentially utilizing both UTM and ATM services depending on the operation or phase of flight.

The phasing and transition from early to more advanced operations require early integration in Commonwealth aviation and transportation roadmaps in the interest of having the Commonwealth fully prepared for the prospects involving uncrewed RAM-L air services. Early

commercial trials and revenue service will provide the operational experience and data required to inform both Commonwealth and operator plans and to move to the later phases:

1. Validation of the vehicle attributes (e.g., performance, maintenance schedules, dispatch reliability, operating costs)
2. Validation or evolution of passenger and public acceptance and service demand levels.
3. Technology/infrastructure readiness and requirements
4. Energy infrastructure readiness and requirements
5. Business/economic models and experience to guide further expansion/scaling.
6. Operational data collection with the systems required for later uncrewed operations required for certification and operational approvals of those systems. RAM(L) and uncrewed UAM operations will require very high reliability systems to enable autonomous aircraft operations with passengers on board and in airspace shared with other passenger aircraft. RAM(S) will require BVLOS capability immediately.
7. Regulatory/policy requirements requiring state and local attention.

The figures below provide a more detailed look at the evolution of these three missions.

Figure 3 is a timeline for the RAM(L) mission. This mission would typically be flown by vehicles such as the Xwing or Reliable Robotics remotely operated Cessna 208 Caravans or other certified aircraft modified with the systems needed for remotely operated BVLOS flight, and by vehicles being developed by firms such as Electra.Aero and BETA Technologies. These aircraft are of sufficient size to carry a pilot and cargo or passengers and utilize various fuel sources including legacy aviation fuels, hybrid power trains, and battery-electric. In effect these aircraft are bringing new advanced-aviation vehicle technologies to today's cargo operations and, in the process, opening new markets by combining cross county regional flight with access to heliports/vertiports or pocket airports (the ability to operate into landing site with ultra-short runways, on the order of 300 feet in length). Introduction of remote piloting capability alters the cost structure and offers the promise of lowering the cost of air cargo and opening services to more communities.

These figures depict three tiers of information; (1) whether the vehicle is crewed or not (onboard vs Remote Pilot (RP) or Optionally Piloted (OP) or autonomous, (2) the types of airspace and landing facilities used, and (3) the implications for several categories of infrastructure. These categories are not all-inclusive. There are further implications for policy, community engagement, and multi-modal connectivity, among others.

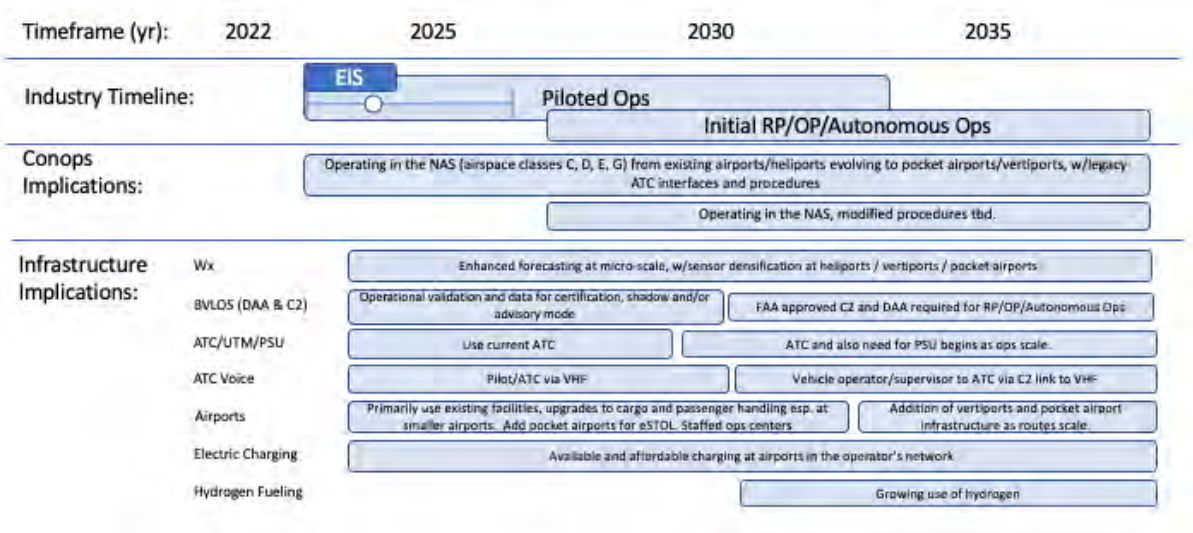

Figure 3 - Notional RAM(L) Timeline

In the mission for RAM(L), press releases, trade press, and discussions within industry suggest that every aircraft OEM and service provider intends to begin revenue services (EIS) with onboard pilots. Remotely piloted operations are to be introduced at a later date as the necessary technology is developed and certified. The immediate focus for most of these firms is initial certification of the vehicles and early revenue service and ROI. This is an important scheduling factor for the industry and for Commonwealth of Virginia actions as the early operations may require less infrastructure than later operations, provide numerous early benefits, and provide the operational experience with RAM to guide future Commonwealth decisions and support the following outcomes:

1. End-to-end validation of aircraft performance airport, airport operations, charging infrastructure where required
2. Testing and validation of infrastructure and technologies required for the uncrewed operations to follow such as DAA, C2, digital voice to ATC, and PSU.
3. Early ROI for those investors supporting the industry
4. Initial validation and refinement to business models and demand predictions
5. Initial benefits to communities with the service and data to inform Commonwealth future investments

EIS for RAM(L) is imminent. The most aggressive provider intends to install their remote pilot systems into their aircraft in 2023 for R&D testing and evaluation in crewed revenue operations in preparation for EIS with the first remotely operated revenue flights in 2025[13]. While such aggressive schedules might not be met, this illustrates the current industry approach of leveraging piloted revenue operations in the near term for the testing and validation of BVLOS systems needed later. Most providers however are in the aircraft certification process with some expected to achieve certification in the 2024-2025 timeframes, again for crewed operation at first. Estimates for the date when remotely piloted cargo operations are taking place vary considerably among industry experts consulted. A notional confidence interval bar is depicted in this figure in

[13] https://www.flightglobal.com/safety/xwing-seeks-to-build-safety-case-for-autonomous-flight-in-trials-with-faa/151198.article

the “Piloted Ops” bar. Similar confidence interval bars can be drawn for other aspects such as remote crew operations. In general, the lower the current Technology Readiness Level (TRL) and the more advanced the technology, the larger the uncertainty will be[14]. Timelines and uncertainty quantification need to be more rigorously developed as the Commonwealth begins to make decisions around RAM/UAM support.

In terms of ConOps, these aircraft will operate in the same airspace and ATC environment as current crewed cargo aircraft. This will typically involve cargo loading at an airport, filing an IFR flight plan, and operating enroute in the Victor Airway structure at altitudes generally below 18,000 feet AGL. As remote pilots and autonomous operations are introduced there is the potential for some procedural modifications to be required, however the industry recognizes that the path to commercial viability is dependent on fitting into the current ATC system rather than attempting to modify it.

The key infrastructure takeaways for the RAM(L) mission are:

1. Airspace access concepts frequently discussed in the context of long-term, highly mature and high pace UAM operations (for example NASA’s UAM Maturity Level (UML) 4) are not required for early revenue service. These piloted operations will be conducted within the existing airspace and ATC environment and items such as PSU, and UAM corridors are not required, potentially through the remainder of this decade. However, the piloted operations provide the means for developmental testing, standards development, validation, and certification of the PSU, DAA, C2, digital voice to ATC, and other systems required for the uncrewed operations to follow.
2. The remote pilot operations that may begin as early as mid-decade will require additional systems to enable BVLOS operations. These systems will require significant testing and operational data to enable certification and operational approvals. These technologies include highly reliable Detect and Avoid (DAA) and Command and Control (C2) communications with the aircraft at all altitudes as well as ATC voice relay from the operator to the aircraft and to ATC. In some cases, the DAA capability is being built into the aircraft rather than requiring ground-based solutions at first.
3. New airports (vertiports) are not required at first, absent an operator identifying a specific business opportunity. Few eVTOL aircraft are being designed to operate the RAM(L) missions, with fixed wing vehicles dominating. The missions will typically be flown from existing airports, possibly with enhancements to cargo facilities or (when passenger service is feasible) passenger lounges and handling facilities. As newer aircraft come online that can use heliports and pocket airports, and as business models and demand predictions are validated, there will be need for additional vertiports or pocket airports in select locations. More research is required with enterprise logistics and passenger operators to assess future airport needs.
4. Some of these aircraft use current aviation fuels. Others are battery electric and will require installation of appropriate airport charging facilities. The extent to which charging

[14] David J. Moorhouse, Air Force Research Laboratory, *Detailed Definitions and Guidance for Application of Technology Readiness Levels*, J. Aircraft, Vol. 39, No. 1

infrastructure is needed will be dependent on the expansion plans of the specific operators.

The RAM(S) mission presents a modified set of ConOps and challenges for middle-mile cargo logistics. A plausible timeline is shown in Figure 4. This mission would be typically flown by vehicles such as the Elroy Air Chaparral. This vehicle cannot carry a pilot and will be always remotely operated/autonomous. The vehicle size and distance to be covered by this mission suggests that they will routinely be operating above the UTM altitude domain (above 400 ft AGL) and mixing with lower altitude general aviation traffic while enroute. The mission appears to primarily target operations at shipping hubs and cargo sorting facilities (off-airport). For example, a March 2022 announcement by FedEx Express mentions "will develop plans to test Elroy Air's Chaparral autonomous air cargo system within the company's middle-mile logistics operations, moving shipments between sortation locations." The vehicles are also suited for humanitarian missions and DOD applications where various procedures for operation of smaller UAS and emergency response aircraft may suffice.

The trade press and publicly available information does not provide significant insight into the airborne concept of operation for these RAM(S) missions; that is, by defining the airspace classes to be used or avoided, phasing considerations for introduction and management of BVLOS challenges. To be operationally feasible these missions may need to address similar challenges as are limiting sUAS in BVLOS operations in the LAM missions, while also requiring high reliability DAA and certifiable C2 at higher enroute altitudes where general aviation traffic may be encountered. A highly notional timeline is shown. Additional details of the mission and airspace operations concepts are needed for detailed analysis. Key takeaways include the following:

1. Relative to RAM(L), the RAM(S) mission will embrace remote operations for entry into service and is likely to require highly reliable, certifiable DAA and C2.
2. The initial entrant uses aviation fuel and hence does not require new charging networks.
3. More detail of the operational RAM(S) ConOps is needed to add confidence to the implications for ATC, DAA, C2.

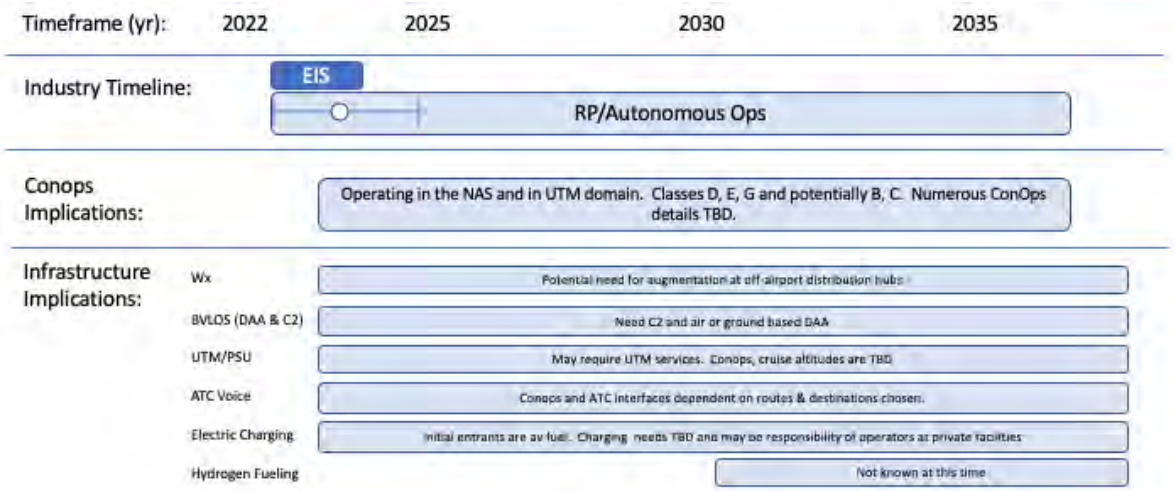

Figure 4 - Notional RAM(S) Timeline

The UAM mission (Figure 5) is the AAM application most discussed in the press and in NASA and FAA documents. These are the urban, short-range eVTOL air taxi operations that most often come to mind when AAM is discussed. Numerous aircraft are in advanced phases of airframe certification and more than one provider intends to be operational at low volume as early as 2025.

Only one OEM in the UAM space (Wisk[15]) has indicated intent to enter service with autonomous vehicle operations, notionally around the end of this decade. UAM revenue operations will face the same autonomous systems certification and BVLOS challenges as L-UAS when autonomous operations begin. Most OEMs intend to begin operations with onboard pilots for some time as a faster path to certification. This will enable ROI in a reasonable time frame allowing OEMs and operators to achieve sustaining revenue, begin the process of passenger and community acceptance, and build operational experience with air taxi services while working towards the certification of autonomous systems.

The phasing of operations and related infrastructure for UAM are similar to the RAM(L) mission, in the following ways:

1. Operations begin with existing airports/heliports and airspace/ATC procedures
2. Electric charging stations are required at relevant facilities
3. Gaining operational experience and validating performance and business models early leads to the knowledge needed to define expansion of service
4. Test and in-service validation of the ConOps and DAA, C2, PSU, and digital voice to ATC systems for later remote/autonomous operations
5. Addition of vertiports and charging stations required as demand scales.

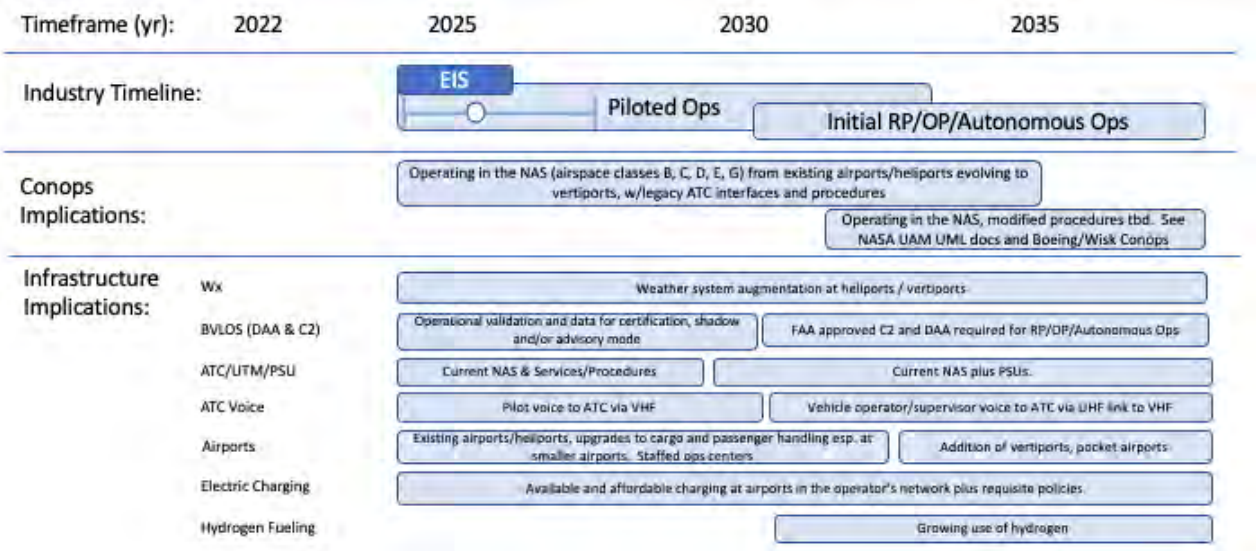

Figure 5 - Notional UAM Timeline

[15] Boeing and Wisk, *Concept of Operations for Uncrewed Urban Air Mobility*, September 2022

Given these missions and likely phasing, the question arises as to the priority for attention and support by the Commonwealth of Virginia. Note that this discussion is subject to the scope of this committee (RAM and UAM only) and does not address priority with respect to LAM and small UAS operations. The state has been highly proactive in LAM for some time and the assumption is made that support for LAM industry growth in Virginia will continue in parallel with support for the emerging RAM/UAM components of AAM. Discussions with industry, within the RAM/UAM Committee, and VAAMA at large suggests the following considerations:

1. RAM(L) is likely to be the first revenue mission in Virginia due to:
    a. Initial services will begin with currently certified aircraft types retrofitted with remote-pilot systems. First revenue operation (with crew onboard) while testing the remote piloting systems are expected by one vendor to begin as early as 2024. This vendor is currently operating cargo routes with these aircraft in close proximity to Virginia (eastern North Carolina), opening the potential for NC partnerships and expansion into Virginia.
    b. This mission initially involves no dependency on passenger acceptance or demand as cargo is being transported and shipping demand can be more reliably forecast.
    c. The safety case should be more easily made with cargo as opposed to passengers.
    d. Immediate benefits to underserved communities are possible. Discussion within this committee suggested that RAM is important not only for improving service to underserved communities, but also for reversal of the ongoing decline of existing services to smaller communities.
2. The Commonwealth can expect that UAM will evolve first in the Northern Virginia/Washington DC region.
3. RAM(S) can potentially become an important link in the Virginia logistics network, integrated with other assets such as Port of Virginia, trucking industry, logistics hubs, and last mile delivery systems. More detailed knowledge is needed from the service providers and potential users of this mission to develop detailed support initiatives. Rollout of this service may be delayed by the challenges of BVLOS operations, again depending on more detail of the intended ConOps.
4. Regional efforts in neighboring states appear to be supportive of RAM use cases and may provide collaboration and partnering opportunities. These include RAM route networks in North Carolina and the Chesapeake UAS Route Network (CURN) efforts in Maryland.

Findings

1. The AAM industry is in the early stages of the innovation S-curve, prior to the transition from the Early Adopter to the Core Growth phases of market penetration. The OEM industry has developed a broad range of vehicle configurations, and it will be some years before dominant eVTOL aircraft configurations evolve. The fundamental propulsion, structures and materials, aerodynamics, and stability and control technologies are developed. The airspace management systems and architectures, the pilot certification and licensing processes, and operational specifications for commercial services for remotely and autonomously flown RAM/UAM aircraft have yet to be fully qualified. The most viable

combinations of aircraft design and performance with business models, infrastructure, and other factors have yet to be proven through market experience.

2. Infrastructure needs are dependent on both the mission (RAM/UAM/LAM) and the timeline of their maturation. Mission differentiation is required for understanding the relevant concepts of operation, interfaces with airports, energy infrastructure, airspace, digital voice to ATC, DAA, and Communication/Navigation/Surveillance (CNS) requirements. While AAM is often associated with autonomy, it is actually enabled by many vehicle advancements. With a few exceptions, RAM and UAM are expected to operate with onboard pilots for some time, providing revenue and economic benefits[16], with autonomous operations becoming generally feasible later. The piloted phase provides the foundation and flight hours required for the validation of the systems required for the autonomous operations to follow. This gradual maturation of the vehicles and operations has significant implications for Commonwealth infrastructure investments.
3. The remote pilot and autonomous operations will require certified and approved DAA and C2 systems for BVLOS. These systems will need to meet more demanding reliability and performance requirements than is the case for sUAS operating in the UTM domain and will require considerable in-service operational testing to gain the data needed to certification and approvals. Hence, the ability to test these systems becomes relevant immediately. This means that when considering "test range facilities" for Virginia's AAM support, we see the need for evaluation and validation of ConOps and BVLOS systems for regulatory satisfaction, using the large number of flight hours that can be gained using commercial routes and operations by crewed aircraft with the BVLOS systems operating in shadow or advisory mode.
4. State-level efforts to advance concepts and standards could include being a convenor that incentivizes industry to want to participate/support activities in Virginia. See ND, NY, and OH as examples of state support for start-up infrastructure to attract investment from stakeholders. These same activities would be aligned (and even leverage) with federal efforts to ensure standards and ConOps are not divergent with the national level roadmap. Having a sandbox to test that could lead to a commercialization opportunity is ideal, as we don't want to be dependent on government funding beyond what is necessary to create the ecosystem required for revenue generating operations.
5. Virginia can play a leading role in RAM/UAM introduction into service in a timeframe of relevance to industry. Literally billions of dollars have been invested to bring AAM to fruition. McKinsey & Company report $7B of disclosed private investments in 2021 alone[17] with that number doubling prior investments. Investors and the industry writ large require return on their investments soon to sustain their viability and secure future investments. Certification, EIS, revenue, and public benefits are accelerated by operating within the current ATM system, with piloted aircraft, until such time as autonomous systems can be certified. Even UAM, in the mid-term[10], will rely on existing ATC services, procedures, and voice communications rather than on the UAM concepts suggested by the NASA UML-4

[16] NEXA Advisors LLC and UAM Geomatics, Inc., Virginia's Advanced Air Mobility Future, AAM's economic benefit for the Commonwealth, January 2023

[17] https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/future-air-mobility-blog/a-milestone-year-for-future-air-mobility

concept of operation. This has two implications for Virginia; (1) to ensure attention is given to the early industry needs (e.g., airport facilities, AAM friendly policy) to begin service and (2) to provide the environment needed to validate the DAA, C2, digital voice to ATC, and PSU systems needed to launch and scale autonomous operations.

6. Virginia has an advantage for introduction of RAM/UAM services in that all of Virginia's public use airports have GPS approach capability and have AWOS-3 systems on the NADIN; this is an essential feature of filing legitimate flight plans by Part 135 operators. This bridge will be needed for transitioning from R&D testing to EIS, and it is found widely only in Virginia. While other states are following suit, VA has a significant lead.
7. The short timeline leading to the potential introduction of RAM/UAM services suggests a sense of urgency for state and regional/city land use and transportation planning and preparation for AAM services.
8. The complexity of the AAM domain and its evolution argues for early development of a Commonwealth leadership structure to provide:
    a. Market segmentation to define mission-specific strategies
    b. A requirements-driven project management approach, informed by the needs of potential AAM service providers, with requirements tracing against ConOps, goals, and deliverables.
    c. Proactively managing uncertainty via means such as defining decision points with entry and exit criteria, defining the data or operational experience or studies needed to meet these decisions, and quantifying and updating confidence intervals concerning key events. Examples of uncertainties to consider include certification dates for various vehicle innovations (powered lift eVTOL, autonomy certified for commercial operations), validation of business models and pace of scaling, passenger and community acceptance, partner commitment and funding, BVLOS approvals, and the evolution of policy and regulations and standards.
    d. Managing collaboration and support across numerous Virginia departments in decision-making and plan formulation. This domain is inherently a transportation system and capability development in both the aviation domain and in multi-modal connectivity (logically involving the Secretary of Transportation and Department of Aviation (DOAV)). The process also can leverage the foundation established by Secretary of Commerce and VIPC during many years of fostering the unmanned systems industry in the Commonwealth. States that are making significant progress in AAM typically have strong Administration and Transportation leadership.
    e. The DOAV has aviation expertise but does not report to the Virginia Department of Transportation. The DOAV budget comes from aviation operations excise taxes, not from the general fund. Without an increase in funding, it will be challenging for DOAV to play a significant role in staffing or funding AAM-related initiatives. However, the DOAV does report to the Secretary of Transportation where needed resources may be found.
9. The multi-disciplinary, multi-agency, multi-modal, and public and private sector stakeholder interests in AAM argues for the consideration of a Public-Private Partnership (PPP) to accelerate the progress and reduce the risks for participants, working toward commercial RAM and UAM services in the Commonwealth. Implementing AAM infrastructure in a PPP format between the state, the federal government, the industry,

and public/private funding sources will dramatically reduce the need for public funding. Such an organization requires a third-party facilitator that would most effectively be hosted by a state organization with the human, physical, and fiscal resources for leadership of the endeavor.

10. The VAAMA has been in discussion regards Minimum Viable Infrastructure (MVI) for AAM. This concept is applicable to LAM. Commercial operations have begun and the singular major obstacle to scaling is airspace access and systems enabling uncrewed BVLOS operations. The term is avoided here in discussing RAM and UAM to stress that infrastructure needs vary by mission and by time phase (entry into service vs. scaled) and encompass both crewed and uncrewed missions.
11. The evolution of S-UAS industries in Virginia play a significant role in advancing the economy in the state and the STEM and related opportunities for workforce development. These advancements have benefits to the Virginia roadmap for RAM and UAM advancements that have yet to be quantified on an engineering and financial basis. See Appendix C for a discussion of engineering considerations.

Recommendations

The RAM/UAM Committee produced 13 recommendations to establish Virginia's leadership in the Regional Air Mobility and Urban Air Mobility market segments of AAM.

- Adopt an overarching strategy to focus on the needs of the nascent AAM sector today while creating the conditions to support a more mature market.
- Quickly establish senior executive leadership and resources to coordinate state initiatives, manage a system engineering process and decision points, and engage city and state land use and transportation planners.
- Ensure an AAM-supportive policy and regulatory environment.
- Respect the unique aspects and concepts of operation of each major AAM mission category (RAM or UAM), and the phased needs of these market segments in developing relevant policy, initiatives, and infrastructure.
- Adopt a strategy of advancing RAM and UAM by facilitating a series of operational demonstrations and trials to tackle major challenges.
- Develop an environment to facilitate operational demos, early revenue trials, and development of beyond visual line of sight, concepts, technologies, and standards.
- Leverage partnerships with neighboring states to leverage resources and harmonize policy, operational environments, and infrastructure.
- Perform an assessment of Virginia public use airports to assess advanced air mobility demand and infrastructure needs. Consider leveraging Virginia Small Aircraft Transportation System Corporation (VSATS) capabilities to support this assessment.
- In alignment with assessed AAM demand, perform physical and/or digital infrastructure improvements at select Virginia airports to accommodate.
- Consider potential dual use concepts and technologies and infrastructure for the civil RAM mission and DOD cargo logistics requirements to potentially leverage investments being made to support DOD.
- Consider the infrastructure and policy environment needed to attract RAM and UAM operations centers to Virginia airports.
- Collaborate with the industry and the FAA to define fleet high-density procedures for Virginia's public use airports.
- Assess the potential for leveraging sUAS technology, infrastructure, and operational capabilities in Virginia, as a basis for attracting RAM and UAM.

These recommendations are provided in greater detail below.

1. The Commonwealth of Virginia is encouraged to adopt the framework set out by Deloitte in their report to the New Jersey National Aerospace Research and Technology Park; *To adopt an overarching strategy of focusing on the needs of the nascent AAM sector today while creating the conditions to support a more mature market.* As noted earlier, literally billions of dollars have been invested to bring AAM to fruition, and OEMs and operators intend to bring AAM to revenue service as early as feasible and well before the systems are certified for autonomous or uncrewed BVLOS operations, and before longer range needs such as PSU and UAM corridors are researched, developed, and approved. Enabling that entry phase of AAM will provide early economic and public transportation benefits while positioning Virginia as a leader in AAM and position Virginia to support the longer range research and development and commercial opportunities. Planning is required for a phased approach to "enable-accelerate-scale" in time frames of approximately 0-3 years, 4-9 years, and 10-15 years respectively, with state initiatives phased to address the time frames as needed. Failure to seize the opportunity to support AAM entry into service may delay the potential economic benefits to Virginia for a decade.
2. Establish as quickly as possible the executive leadership and management resources needed. We suggest:
    a. Recruit partnership leadership who has senior executive experience and aviation domain expertise from Government or industry. This individual would report to the governor's office, ideally through the Secretary of Transportation. This leader would manage the interests of both public and private sector partners in a collaboration alliance, be a focal Virginia voice and point of contact for the industry, coordinate the Virginia plan with national strategies, and represent Virginia to Federal executive level work groups (e.g., the advanced air mobility interagency working group created by Public Law 203, Advanced Air Mobility Coordination and Leadership Act). This leader would represent Virginia in multi-state partnerships, to the industry nationally and to international interests.
    b. A third-party facilitator with senior management experience for project management. This individual would drive the systems engineering operation, market analytics, ConOps, technical requirements documentation, regulatory requirements tracking, project control (budgets, schedules), financial management and documentation, and deliverables management. The RAM/UAM OEM and operator community and subject matter expertise (SME) should be well represented and intimately engaged in development of ConOps and requirements.
    c. Engage city and state land use and transportation planners as early as feasible to begin assessing the implications of RAM and UAM to logistics networks, city transportation infrastructure, and multi-modal connectivity.
3. Improve cross-agency coordination in Virginia and to legislature to avoid policy or legislative barriers to entry. This would be one function of the senior executive. For example, vertiport access laws based on prior helicopter noise issues may be overly restrictive for the low-noise eVTOL aircraft in development. Public or legislator perception of eVTOL aircraft as being like sUAS could lead to counterproductive and non-relevant legislation around privacy or overflight of private property. Early imposition of user fees to

fund the necessary state leadership could act as a disincentive for operators to set up in Virginia. Consider tax codes and the impact on electric charging costs at airports. However, the senior executive should have a fund source to help answer or quantify requirements that come up as concepts mature.

4. Develop mission-specific roadmaps and strategies based on industry progress and timelines, and flow down to ConOps and associated policy, incentives, and infrastructure needs. Maintain roadmaps to document the expected maturity path of the industry, define phasing of initiatives in alignment with recommendation #1, establish decision points, and proactively manage the schedule uncertainties and risks. Industry rollout plans, operational experience gained, and ConOps will influence both the infrastructure needs and the policy/regulatory environment needs. Operational routes, airport procedures, business considerations, and policy/regulations should be discussed in an integrated manner. The roadmap development has begun in this paper and should be further developed with more rigorous analysis and with additional engagement by the aircraft OEMs and the service providers. This development must be in alignment with federal efforts (FAA, FCC, other), facilitated with coordination with appropriate FAA, NASA and industry working groups such as the RTCA, SAE, VFS and GAMA. Virginia must be aware of and aligned with evolving federal/industry consensus standards to avoid inappropriate investments or retroactive compliance with standards.
5. Adopt a Virginia strategy of advancing RAM and UAM by means of industry demonstrations. Attract industry to conduct demonstration flights to Virginia as they become feasible for proofs of concept in end-to-end operations, with passengers as applicable. Demonstrations should target the major barriers to adoption and include ConOps, procedures, business case analytics, sustainability analytics, economic benefit analytics, and airport and ATC interactions. These demonstrations should exercise the procedures and infrastructure needed for near-term revenue operations, per the overarching recommendation that Virginia focus on the needs of the nascent AAM sector today while creating the conditions to support a more mature market. These demonstrations will provide increased confidence in the maturity of the operational concepts, provide firsthand AAM experience for communities and state lawmakers, inform next steps, provide data to the service providers and FAA/NASA, accelerate adoption, generate national attention, and make clear that Virginia is a leader in this space.
6. Establish an operational testing and validation environment (“sandbox”) that facilitates (1) early demonstrations and trial service between locations and (2) the testing of concepts and technologies required for autonomous BVLOS operations and scaling (e.g., PSU, DAA and C2, and high density IFR operations). This operational environment should facilitate AAM operations in the National Airspace System, supported as needed with physical airport infrastructure, DAA and C2 links, state support in coordinating with airports and any federal or state waivers or permitting processes or Temporary Flight Restrictions (TFR), leverage existing infrastructure, and be guided in its design by the time-phased challenges faced by operators. This AAM “sandbox” should provide a favorable environment to perform operational trials, and also enable the supply chain to conduct the technology and standards development needed for operational approvals of scaled and autonomous operations.

7. Investigate multi-state partnerships and collaboration (particularly with NC, MD, and WV) to amplify efforts, jointly represent state needs and advocacy for progress in setting standards to the FAA, and further attract RAM opportunities and routes. Virginia is perfectly positioned for collaboration with these states, and it is advantageous to AAM operators to have similar or same testing and operational environments (policy, infrastructure, procedures) that cross state lines.
8. The DOAV is partnered with the Virginia Small Aircraft Transportation System Corporation, VSATS, a 501c3 company established to support innovation in Virginia airport and airspace systems aimed at leveraging advancing technologies in the service of enhanced safety and operation capabilities for the public use airports in the Commonwealth. The VSATS Board could consider funding a state-wide survey of operators of public-use airports in the state to assess airport management and leadership readiness and interest in use-case-specific AAM capabilities to be served by their airports. This will inform infrastructure needs (e.g., instrument approach procedures and weather information) for the evolving AAM industry.
9. Improve cargo handling and passenger handling facilities at our small airports, and ensure that approved IFR approach procedures and supporting weather systems are available. Per the recommendations above for planning and decision points, facility improvements should be guided by service provider demonstration of viability and a plausible business case indicating that the facility will be put to use, and/or airport-by-airport analysis of the latent demand for passenger and cargo services.
10. Consider potential dual use ConOps for the civil RAM mission and DOD cargo logistics and personnel movement requirements. DOD entities in the Hampton Roads region and beyond have mission needs that employ UAS of the same category as applicable for the RAM missions, and for which similar infrastructure for BVLOS (DAA and C2) might be evaluated. This is not a suggestion for state investments to solve DOD-specific challenges, but to leverage challenges that are shared with civil use cases.
11. Consider the infrastructure and policy environment needed to attract RAM and UAM operations centers (locations for remote pilots, fleet management, maintenance, etc.) to Virginia airports. This may include needs for fiber, broadband, zoning laws, C2 systems, funding for infrastructure, potentially subsidies for early operational trials, etc. These operations centers can become revenue generators for the local municipality.
12. RAM and UAM fleet procedures at airports are ill defined; the Virginia Department of Aviation should work with the industry and the FAA to define arrival and departure procedures that facilitate high fleet utility in the Commonwealth.
13. We recommend focused analysis of the potential for leveraging sUAS technology, business models, and infrastructure and operational capabilities in Virginia, as a basis for positioning Virginia in attracting RAM and UAM industry leaders to manufacture, deploy and operate their businesses in the state.

Summary

Advanced Air Mobility, specifically the domain of Regional Air Mobility and Urban Air Mobility, is rapidly becoming a commercial reality, offering new aviation transportation network options for passengers and cargo, expanding service, and providing economic growth for the Commonwealth. Virginia joins a growing number of states striving for leadership and early adoption of this market.

Time is of the essence for the Commonwealth to capture a position as a leader in AAM. This committee recommends that Virginia adopt an overarching strategy of focusing on the needs of the nascent AAM sector today while creating the conditions to support a more mature market. The nascent AAM sector today has strong incentive to quickly begin revenue services and begin to capture revenue and investor ROI on billions of dollars of private investments. Virginia can capture a leading role in enabling this early service and associated economic benefits, and in the process position us to serve the developments that lead to scaled and more advanced operations in the next decade (supporting a more mature market). Failure to seize the opportunity to support AAM entry into service may delay the potential economic benefits to Virginia for a decade.

Strong senior executive leadership and management with direct backing from the governor's office and with deep aviation expertise and project management discipline is essential to best leverage Virginia's opportunities, build partnerships across Virginia agencies, industry, and other states, and to represent Virginia at the Federal level.

The promise of AAM is at our doorstep and ours to capture.

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Appendix A - Abbreviations

AGL	Above Ground Level
ATC	Air Traffic Control
ATM	Air Traffic Management
AWOS-3	Automated Weather Observing System
BVLOS	Beyond Visual Line of Sight
C2	Command and Control
C2CSP	C2 Communications Service Provider
CNS	Communications, Navigation and Surveillance
ConOps	Concepts of Operation
CURN	Chesapeake UAS Route Network
DAA	Detect and Avoid
DOAV	Virginia Department of Aviation
EIS	Entry Into Service
eSTOL	electric or hybrid electric ultra-Short TakeOff and Landing aircraft
eVTOL	electric Vertical Take Off and Landing aircraft
FAA	Federal Aviation Administration
GAMA	General Aviation Manufacturers Association
IFR	Instrument Flight Rules
LAM	Low Altitude Mobility
L-UAS	Large UAS (for the purposes of this paper weighing more than 55 lb.)
MASPS	Minimum Aviation System Performance Standards
MOPS	Minimum Operating Performance Standards
MVI	Minimum Viable Infrastructure
NADIN	National Airspace Data Interchange Network
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
OEM	Original Equipment Manufacturer
OP	Optionally Piloted
PSU	Provider of Services for UAM
RAM	Regional Air Mobility
RAM(L)	Regional Air Mobility (large UAS or crewed aircraft)
RAM(S)	Regional Air Mobility (smaller, uncrewed UAS)
ROI	Return on Investment
RP	Remotely Piloted
SME	Subject Matter Expertise
STEM	Science, Technology, Engineering, and Math
sUAS	Small UAS
TFR	Temporary Flight Restrictions
TRL	Technology Readiness Level
UAM	Urban Air Mobility
UAS	Uncrewed Aerial System
UML	UAM Maturity Level
UTM	UAS Traffic Management
VFS	Vertical Flight Society
VIPC	Virginia Innovation Partnership Corporation

Appendix B - Lessons from States

A body of literature exists that represents considerable analysis and intellectual investment in discerning the future direction of AAM and the role that states can play. See bibliography items 2 through 10. These reports represent both general industry and FAA/NASA concepts of operation and forecasts, and studies performed specifically for other states to develop strategic frameworks.

The AAM studies prepared for various state governments generally provide a scope or vision of AAM, an assessment of the landscape and paths to maturity of the necessary vehicles and supporting ecosystem, an estimate of the economic activity to be generated, and suggest strategies for the states. Much of the assessment of landscape and technology maturity paths are state agnostic and apply to Virginia as well as the states studied. While specific projects and highest value use cases will be state dependent, there is also considerable similarity among the reports in suggesting appropriate state response to the opportunity.

The following industry characteristics were observed across multiple reports:

Use cases:

- Passenger flights within cities and suburbs, and between rural airports and urban centers.
- Fly between city pairs and rural airports at distances currently not served by airlines.
- Airport shuttles
- Business aviation, on-demand air taxi, tourism
- Healthcare access (EMS, non-critical patient transport, Clinic and screening events, delivering medical supplies, organs, blood, plasma, vaccines)
- Air cargo, logistics
- Bridge the rural-urban divide.

This phased introduction of AAM across multiple mission types was recognized by the reports. Notably:

1. Initial operations of UAM and RAM aircraft for the most part will be with pilots on board. The relevant missions include airport shuttles, urban passenger transportation, human organ transport, business aviation, and cargo transportation. These piloted operations will provide significant operational data regarding the aircraft performance, business models, CNS and other infrastructure solutions, and more while testing the technologies and systems required for future remote pilot and autonomous operations
2. Existing airport infrastructure will be used for these early operations both towered and remote “uncontrolled” general aviation airports and heliports.
3. While FAA and NASA ConOps for UAM focus on UAM Maturity Level 4 (high density and highly automated operations, in UAM corridors), the nearer term use of these vehicles will employ pilots and integration with ATC that do not require modifications to the ATC system architecture.
4. Regional Air Mobility, particularly with cargo, is likely to be a nearer term scalable use case than UAM. These RAM operations will use the capabilities of the emerging vehicles to provide lower cost cargo transportation, enable the testing and early adoption of remotely piloted aircraft, and in some cases make use of current ATC interfaces and services. In

other cases, the RAM cargo operations will face the same BVLOS challenges as sUAS do today.

The implications of the AAM maturity evolution for state strategies were well articulated in multiple state reports:

1. While the FAA and industry are following a "crawl-walk-run" approach to technology development and operational experience, the states can support via a *phased approach to "enable-accelerate-scale"* in time frames of 0-3 years, 4-9 years, and 10-15 years respectively with state initiatives phased to address the time frames as needed. As the Deloitte study[18]articulated; *an overarching strategy of focusing on the needs of the nascent AAM sector today while creating the conditions to support a more mature market.*
2. Early establishment of appropriate state level leadership and management structures.
3. Early establishment of AAM R&D hubs, a Center for AAM, or a "sandbox", including a study to differentiate the proposed ecosystem from those in other states.
4. Planning and development for the accelerate and scaling phases to include transitioning to a program management organization leadership structure, expanding ecosystem partnerships, PPP for infrastructure funding and development, and initial revenue operations expanding to routine.

The reports analyzed listed several pillars, or key components of a state strategy, with considerable agreement between the reports:

Deloitte notes four pillars (funding, ecosystem, infrastructure, policy) along with an overarching strategy of focusing on the needs of the nascent AAM sector today (research, develop, test) while creating the conditions to support a more mature market with a strategy tailored to three time phases (enable, accelerate, scale):

1. Funding:
- Dedicated state funding for AAM programs
- Funding to incentivize industry for AAM

2. Ecosystem:
- Focal point within the state to advocate for AAM development
- Whole-of-government approach to support AAM

3. Infrastructure:
- Established AAM environment
- Designated office to manage AAM infrastructure

4. Policy:
- AAM task force responsible for shaping legislation
- Legislation to support the growth of AAM industry

[18] Deloitte Consulting, A Strategic Roadmap for the Development of Advanced Air Mobility, Prepared for National Aerospace Research and Technology Park: New Jersey, June 2022

Appendix C – Linkages Between Infrastructure Needs for RAM/UAM and LAM

It is worth noting that addressing LAM and BVLOS infrastructure challenges may also yield future benefits for RAM and UAM, and addressing RAM/UAM may benefit LAM. sUAS BVLOS operations can serve as a cost and safety risk-effective proving ground to support larger scale LAM and RAM operations. sUAS BVLOS operations can be an effective steppingstone to AAM in the areas of infrastructure, procedures, safety risk assessment and mitigation, standards and requirements development, and regulatory approach.

Many of the infrastructure technologies such as command and control communications links, surveillance coverage for traffic deconfliction of both crewed and uncrewed vehicles, ground and airborne detect and avoid (DAA) technologies and procedures, data networks and operations centers to oversee and monitor operations and network infrastructure health can be developed and proven in support sUAS BVLOS operations in the low altitude environment and then scaled up or modified to meet more rigorous standards to support more advanced RAM and UAM operations with people and cargo. Likewise, these capabilities under development for RAM and UAM will be proven in airspace domains and operations appropriate for those missions and will yield technologies and procedures of benefit to LAM.

Operational procedures such as traffic deconfliction during altitude transitions, operations tracking and monitoring, system health monitoring and steps for the gracefully system degrading during outages, and command and control can be developed and tested at a more cost effective and lower risk approach on a limited scale in the sUAS BVLOS environment. While these procedures cannot cover the full domain of RAM and UAM operations and their associated interfaces with airports and ATC, valuable insights will apply. Likewise, the procedures developed for RAM and UAM will inform interfaces to the LAM environment.

Operational safety risk assessment and supporting mitigations can be developed and assessed in a cost-effective manner in a sUAS BVLOS environment. Both air collision risk with legacy crewed aircraft and ground collision risk to third parties can be quantitatively assessed and mitigations both technically and procedurally developed that can pave the way for upscaled LAM and RAM operations.

One of the major challenges for both LAM and RAM/UAM is specific standards to support the establishment of requirements for the design and development of vehicles and supporting infrastructure. The sUAS community is striving through organizations such as ASTM, and RTCA to develop standards that can support the development of system requirements for the autonomous, uncrewed operational environment. Likewise, the RAM/UAM community is striving through RTCA and others to develop standards and procedures. These standards and the processes, procedures, expertise, and relationships of the working groups that develop them can be leveraged between the LAM and RAM/UAM environments.

Finally, the regulatory path forward for AAM is challenging. Developing a new, and innovative air transportation system must not increase the degree of risk in the National Airspace System. The sUAS industry has worked with the FAA, and other organizations such as the FCC to help introduce new technology and operations. There are many lessons learned over the past few years that can help guide and develop the path forward for AAM regulatory operational approvals.

While procedures and infrastructure technologies have numerous crossovers between LAM and RAM/UAM, the applicability of specific concepts across domains must be assessed considering the unique standards and requirements of each. For example, a specific ground based DAA system (radar or acoustic for example) might support both UTM below 400 feet AGL and RAM/UAM missions flying at 2000-3000 feet, or it may not. Likewise, UAM infrastructure needs may be unique to the larger aircraft and not apply to LAM, for example eVTOL charging stations. There are differences between these domains in certification standards; land-side infrastructure requirements; airspace services requirements; operator training and certification; command and control spectrum and systems; CNS requirements; aeronautical information needs; phasing of infrastructure needs; and culture.

As one example, industry recommended Minimum Operating Performance Standards for DAA systems for RAM and UAM missions can be found in RTCA DO-365C[19]. This document applies to uncrewed aircraft operating in the NAS while transiting and performing extended operations in Class D, E, G airspace and transiting Class B and C airspace. A multitude of factors are considered to include surveillance volumes, alerting times, positional and altitude accuracy, resolution advisories, latency, C2 requirements, health monitoring requirements, environmental, and more. RTCA DO-365C explicitly does not apply to small UAS (under 55 lbs) operating in the low-level environment (below 400'). Viable DAA system developed for the LAM mission may or may not meet the stringent performance requirements of DO-365C for RAM/UAM flights.

Likewise, RTCA DO-377A[20] provides industry recommended performance standards for C2 link systems. Again, the document scope explicitly omits UAS operations performed under the 14 CFR Part 107 regulations. Considerations such as reliability, range, altitude coverage, digital voice to ATC latency, and cyber security needs of large UAS operating alongside legacy aircraft in the NAS are not likely to be met by the systems currently employed for sUAS operations.

The nuance is that while there are numerous links between the two domains and there are lessons to be learned in each that will support the other, we must employ engineering analysis and attention to the unique mission requirements and applicable standards to determine when an investment in one domain may apply to the other. Absent this analysis, the Commonwealth of Virginia may incur risk to investment ROI, schedule, and pace of AAM adoption if unqualified assumptions are made that sUAS infrastructure investments will also support RAM and UAM.

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[19] RTCA DO-365C, Minimum Operational Performance Standards (MOPS) for Detect and Avoid Systems (DAA), September 15, 2022.

[20] RTCA DO-377A, Minimum Aviation System Performance Standards for C2 Link Systems Supporting Operations of Unmanned Aircraft Systems in U.S. Airspace, September 16, 2021