The National Academies of
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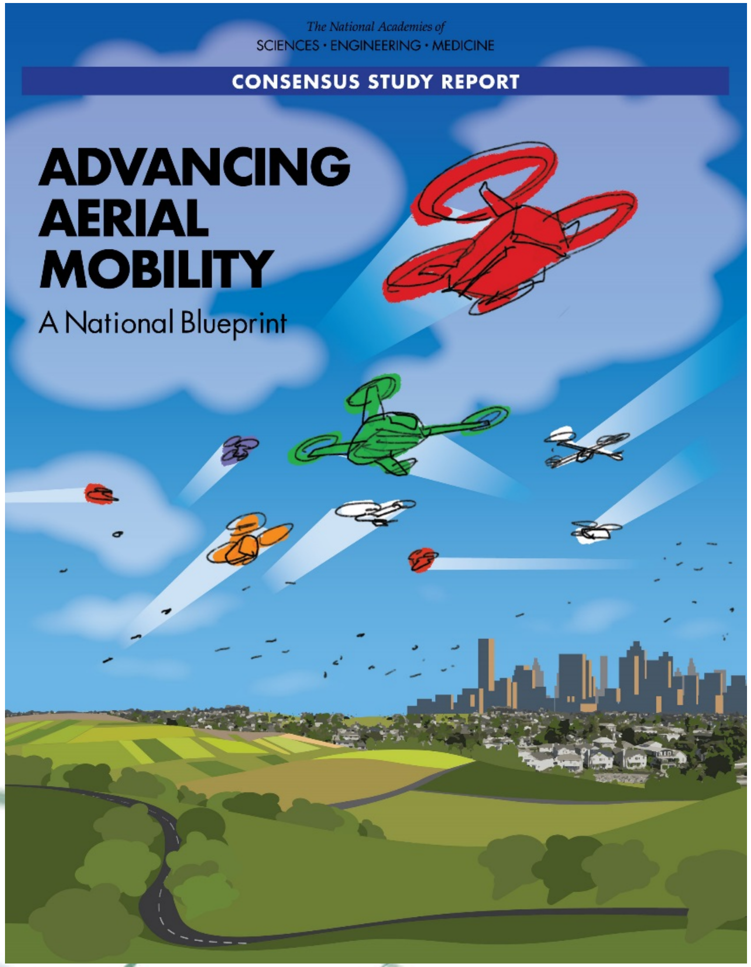
AERONAUTICS AND SPACE ENGINEERING BOARD (ASEB)

Advancing Aerial Mobility: A National Blueprint



The Committee on Enhancing Air Mobility
Chair: Nick Lappos

Report Summary April 2020

Outline of this Debriefing

- Committee Tasking and Committee Activities
- The Committee's Vision for Advanced Aerial Mobility
- Recommendations to Achieve this Vision
- The Path Forward

Committee Statement of Task

Prepare a report that will:

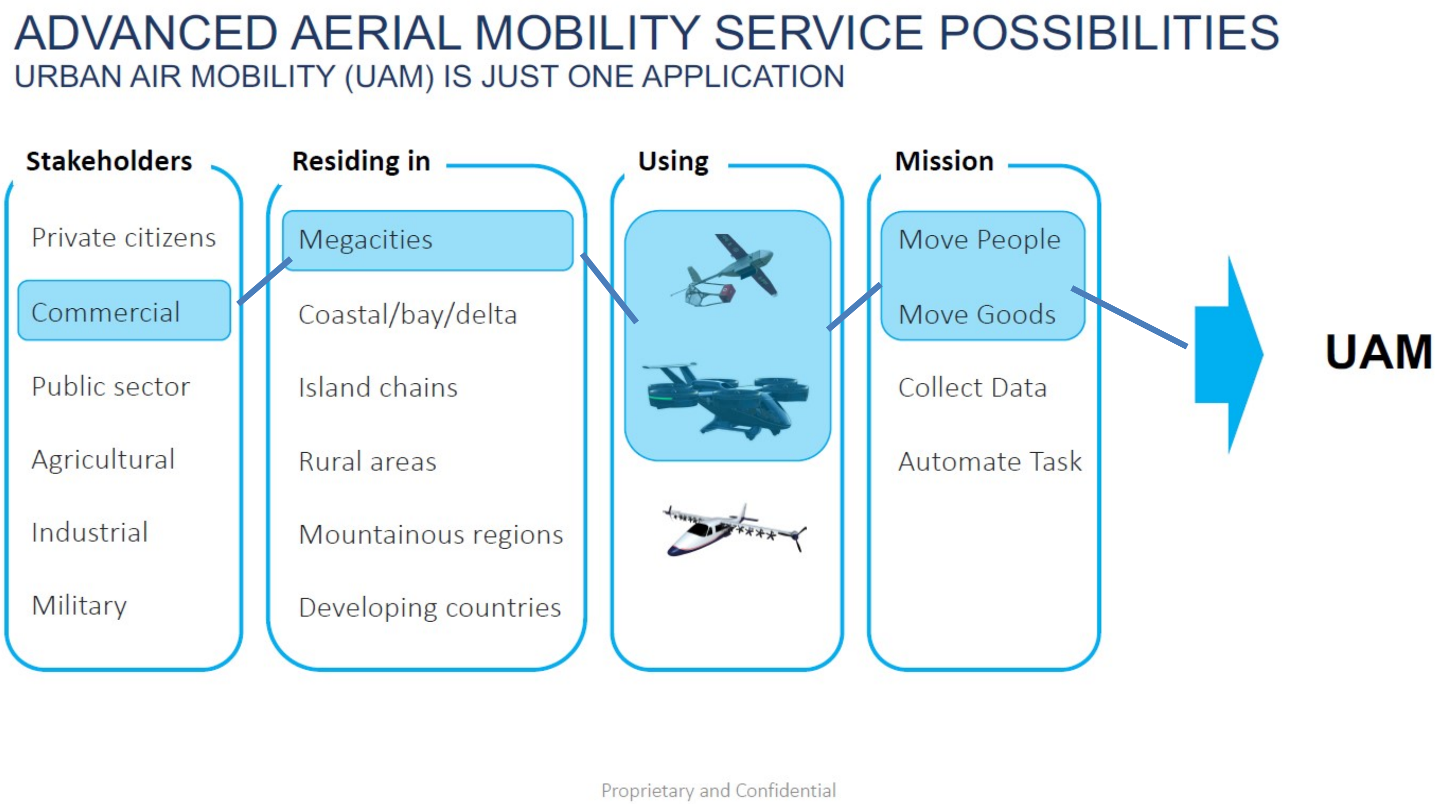
- Develop and **discuss a recommended national vision** for UAM.
- Identify and prioritize by group the **key technical, economic, regulatory, and policy barriers** to achieve the vision.
- **Assess the potential impact of highly entrepreneurial approaches**, including those that could be implemented by non-aviation industry entrants, in achieving the vision.
- **Recommend key research projects** that NASA, other government agencies, industry, and academia could employ to overcome the barriers and facilitate likely approaches to achieving the vision.
- **Assess the potential and benefit for a public-private partnership in** addressing the technical, economic, regulatory, policy, and other related (e.g., urban planning) requirements.

Committee Members

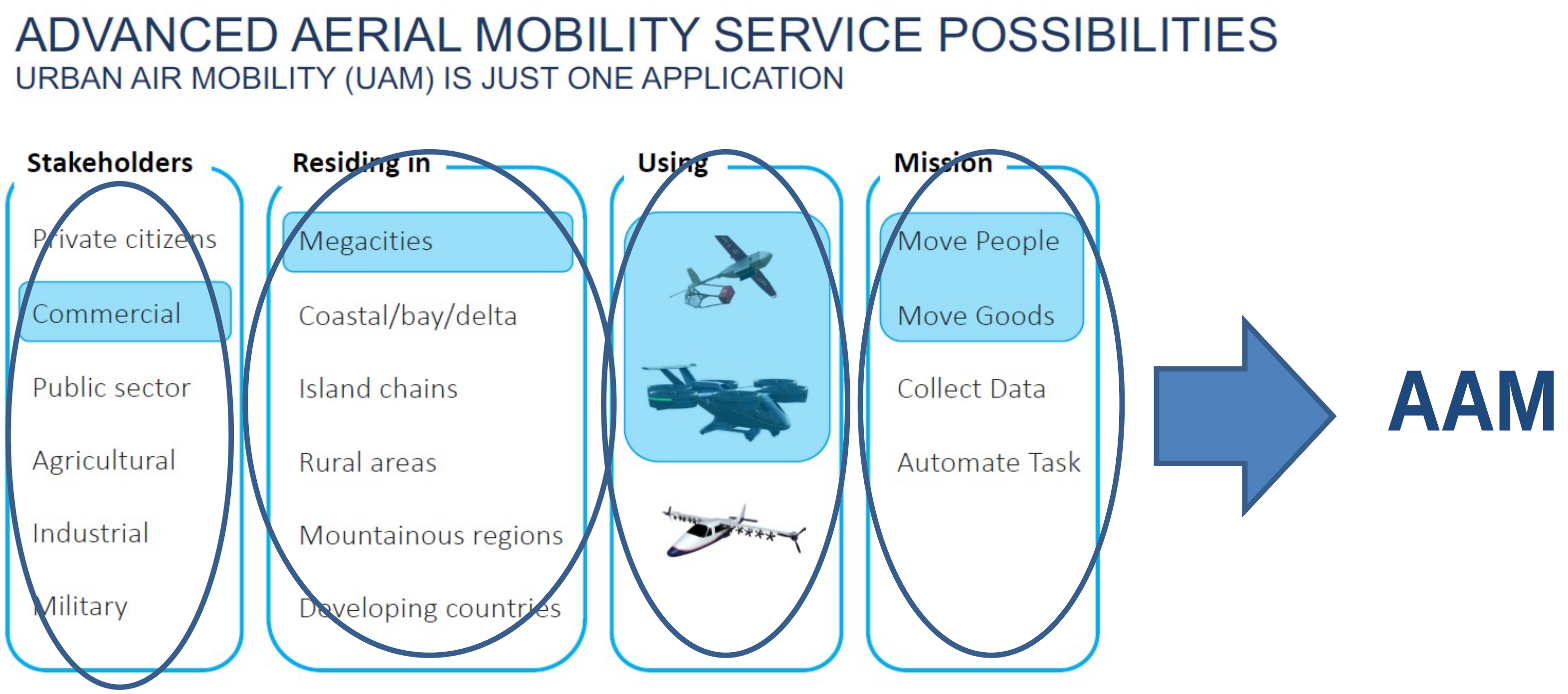
COMMITTEE ON ENHANCING AIR MOBILITY

- Nicholas D. Lappos, Chair, Sikorsky Aircraft (Lockheed Martin)
- Ella M. Atkins, University of Michigan
- James G. Bellingham, Woods Hole Oceanographic Institution
- Atherton A. Carty, Lockheed Martin Corporation
- Daniel DeLaurentis, Purdue University
- Nancy G. Leveson, Massachusetts Institute of Technology
- George Ligler, GTL Associates
- Lourdes Quintana Maurice, DLM Globala Strategies
- Paul E. McDuffee, Boeing
- Vineet Mehta, AIRXOS (a GE Venture)
- Constantine Samaras, Carnegie Mellon University
- Peter Shannon, Radius Capital

Limited Case: Urban Air Mobility



General Case:
Advanced Aerial Mobility



The Ultimate Vision for Advanced Aerial Mobility

The committee envisions that the Nation can achieve an advanced aerial mobility system that can:

- **Support high-scale flight operations** for a number applications
- **Shared airspace occupied by many classes of vehicles**, separated by networking technologies
- **Use a variety of vehicles**, developed by both new entrants and well-established entities
- **Carry passengers and/or cargo**
- **Operate both in metropolitan or rural areas**
- **Maintain the highest level of safety** as expected of the National Airspace System
- **Inherently Flexible**
- **Environmentally responsible**
- Capable of **All-Weather Operations**

American Leadership Potential

- **The US is poised to continue its leadership** in the development of new aviation technology
- The committee has heard from a broad cross-section of industry experts: it is clear that **this market is geared for massive and rapid evolution if the regulatory framework is there to support it**
- **US industry possesses the resources, capital, and capability** to execute on addressing the challenges posed by implementation of advanced aerial mobility at increasing levels of complexity and density.
- **U.S. leadership in advanced aerial mobility is <u>in no way assured</u>,** despite our strong legacy in aerospace. The new technologies enabling advanced air mobility are widespread across developed and developing countries, drawn in many case to their lack of regulatory frameworks. Their fundamental nature lowers the barrier to entry, despite the complex systems engineering involved.

Recommendations to Achieve this Vision

Recommendation: Form a Coordinated, Joint National AAM Plan

Recommendation: In order to formulate a United States Joint Advanced Aerial Mobility Master Plan, **NASA and FAA** should form a partnership to manage responsibility and accountability across the various stakeholders and **participate in the development of the Master Plan**.

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Recommendations: Prepare the National Airspace System to Integrate AAM

Recommendation: NASA should prioritize research that develops architectures, requirements, and supporting technologies to enable **integrating advanced aerial mobility into a future National Airspace System.**

Recommendation: NASA, in coordination with the Federal Aviation Administration (FAA), should perform research **to extend unmanned aircraft system traffic management concepts to accommodate emerging advanced aerial mobility traffic in all classes of airspace.**

Recommendation: Research to Address: Societal Impact

Recommendation: NASA should facilitate a collaboration with other relevant government agencies—the FAA, Department of Commerce, and Environmental Protection Agency—and industry—original equipment manufacturers and operators as well as academia and non-profit organizations — **to conduct scenario-based studies to assess societal impacts (privacy, intrusion, public health, public annoyance due to noise**, **and welfare, transparency, environmental, inequity, etc.) of advanced aerial mobility vehicles and associated infrastructure**. These studies should recommend a path to implementation that prioritizes maximum public benefits.

Recommendation: Develop the Marketplace for First Adopters

Recommendation: NASA should, within the next year, **establish strategic partnerships with first adopter cargo logistics providers** and relevant manufacturers. The partners should focus on maturation of technologies aimed at deploying autonomous cargo drone delivery of small, medium, and large size within 3 years.

Recommendation: Use the NASA Grand Challenge to Formalize Best Practices

Recommendation: In partnership with industry, NASA should continue building on and enhancing the Grand Challenge program and develop its learning outcomes into **formalized best practices, tools, resources, and training programs** available to all U.S. stakeholders.

Recommendation: Address Safety in Software Intensive Systems

Recommendation: In coordination with the FAA, NASA should support **research on new, more powerful safety analysis tools** that are widely used today that can be applied to software-intensive advanced systems.

Recommendation: Develop Cybersecurity for Advanced Aerial Mobility

Recommendation: NASA should **conduct research and development on cybersecurity** for advanced aerial mobility systems

Recommendation: Develop Certification Techniques for AAM

Recommendation: Working with the FAA certification experts, NASA should **develop potential software and hardware certification techniques and guidelines** to verify and validate the performance of complex software and hardware, including nondeterministic functionality. This NASA research into methods to demonstrate performance will provide valuable input to the FAA, including material for advisory circulars, to help applicants in the certification process.

Recommendation: Research and Develop Contingency Management

Recommendation: NASA should conduct **research, development, and testing of autonomy for contingency management** to support safe advanced aerial mobility.

Recommendation: Create AAM Test Facilities

Recommendation: NASA, in coordination with the FAA, should make allocations of facility resources and airspace and regulatory accommodations **to establish a continuous flight test capability that supports rapid development** of the following:

- Air vehicles;
- Flight operations practices;
- Surveillance and communications technologies/networks;
- Air traffic management systems, leveraging UTM construct and lessons;
- System-wide management systems;
- Noise reduction technologies and operations; and
- Ground infrastructure specific to various applications.

This flight test capability should be designed to enable industry to innovate and commercialize its platforms/applications more rapidly. This effort can build on the progress and assets already in place from existing test range programs.

Recommendation: Establish Public-Private Partnerships

Recommendation: A public-private partnership should be established to facilitate advanced aerial mobility implementation **in a virtual environment to deliver as a near-term capability to define mobility systems and infrastructure requirements**. This virtual environment should complement physical flight and operations testing. The partnership should be coordinated by NASA, in collaboration with the FAA and with coordinated allocation of responsibility amongst the FAA and other relevant agencies, industry (original equipment manufacturers, and operators), and standards development setting organizations. For example, the group could focus on developing guidelines and solicitations for advanced aerial mobility infrastructure deployment.

Recommendation: Establish Data Protocol Standards

Recommendation: A working group comprised of NASA, industry, academia and the standards development organizations should prioritize **research on the protocols, data formats, and data exchange standards that support advanced aerial mobility vehicles** in a geospatial real-time system supporting safety-critical operations across the National Airspace System. The intent should be that the tools developed will provide the necessary clarity to catalyze and enable commercialization of system components by industry.

In Sum

In the development of these new technologies, what the committee recommends is **strong and knowledgeable government regulatory establishment, with FAA, DOD and NASA technologists who are prepared to lead** with guidelines. What is needed to assure continued U.S. leadership **is a clear statement of national will, and a clear master plan and national commitment** to execute it.

Next Steps

Call to Action

Employ The National Academies resources to facilitate:

- Preparation of an AAM/UAM Master Plan for the United States by the end of 2020, by inviting NASA and the FAA to form a team of Government and Industry experts.
- The design and development of a scalable, digital ATM Network that can integrate AAM/UAM into the 21st century NAS, by inviting FAA and NASA to form a team, working in conjunction with Industry experts.

Thank you for Your Attention.

Questions?

Backup Slides

Committee Statement of Task

The National Academies of Sciences, Engineering, and Medicine will convene an ad hoc committee to assess the feasibility of a safe and efficient urban air mobility (UAM) system. In terms of general definition and concept of operations, the committee will consider UAM to be a system for air passenger and cargo transportation within a metropolitan area (including operations over densely populated urban areas), with vehicles ranging from small drones to passenger aircraft with electrically powered vertical take-off and landing (eVTOL) capabilities**. For both manned and unmanned aircraft, the study will focus on a system vision (including interface/integration into broader air transportation systems, ground transportation systems, and smart city systems generally), barriers, entrepreneurial approaches, and research projects that are particular to operation in uncontrolled airspace over metropolitan areas.**

Committee Activities

1st Meeting (May 2019)

- Heard from NASA on their Current Urban Air Mobility Activities
- Hosted Presentation from a Variety of Industry Experts on Potential Use Cases

2nd Meeting (July 2019)

- Discussed the Barriers to the Development of Air Mobility
- Discussed the Infrastructure Needed to Support Expanded Air Mobility
- Heard from NASA on their Market Studies on Expanded Air Mobility
- Began drafting the recommendations of the committee

3rd Meeting (September 2019)

- Committee Reached Consensus on the Issue
- Began Writing the Body of the Report
- Reviewed and Approved the Text of Recommendations from the Committee

Committee Activities

Post 3rd Meeting Activities

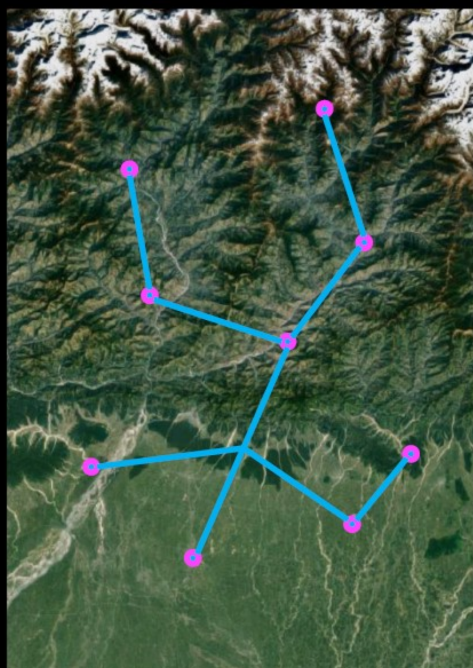
- Continued Discussion on Some Final Points to Address
- Finalized First Draft of the Report
- Achieved Final Consensus on 14 Recommendations to NASA to Facilitate the Development of Advanced Aerial Mobility

Report Review (October 2019 to January 2020)

- Completed External Review with 9 Reviewers

The Current Paradigm of Transportation

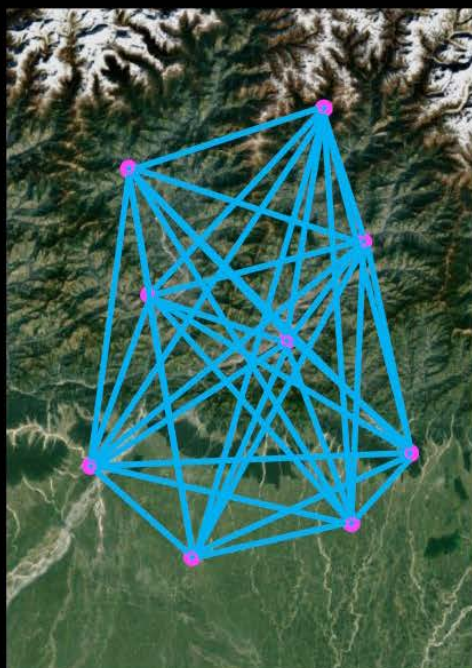
ROADS ARE A LINEAR TRANSPORTATION NETWORK



- Every path must be constructed
- Routes limited by geography
- Routes permanent – for centuries
- Fixed routes inhibit flow changes over time
- Congestion ripples throughout network
- Ongoing maintenance as infrastructure ages
- Difficult to expand in already dense areas

Paradigm Enabled by Advanced Aerial Mobility

AERIAL MOBILITY IS A NODAL TRANSPORTATION NETWORK



- Inherent direct connectivity between every point
- No path infrastructure to build and maintain
- Flexible capacity
- Resilient to disruption
- Small footprint
- Easier to overlay into already developed areas

Technical Challenges 1

- **Integration of Autonomous Vehicles into the Airspace -** Current airspace configuration, operational rules, and procedures did not anticipate the emergence of an autonomous aviation ecosystem. Piecemeal implementation of UAV regulations adds to the cacophony. Current challenges to integrating autonomy into the airspace system include further research and development of core technologies as well as systems engineering to integrate the different components into a system that is fieldable and able to support flight testing.

- **Communications and networking** - New communication methods are needed to support greater scale and also to support the requirements of unmanned or autonomous aircraft. There is no globally accepted spectrum for autonomous system command and control.

- **Scalability -** A major limiting factor in scalability remains the limitations of human operators throughout the system to safely manage the demands of handling additional density. Overcoming these limits necessarily involves increasingly replacing human responsibilities in these roles with automation.

Technical Challenges 2

- **Safety -** The system-wide-level complexity of an airspace system supporting advanced aerial mobility can introduce unforeseen interactions that create new hazards to plan for and mitigate. Safely implementing this new capability in the airspace system will first require gaining experience in a low-risk environment and gathering data with which to learn and improve.

- **Security -** Aspects of security today that are based on trust between humans such as voice communications between pilots and air traffic control (ATC)will need to be approached differently as digital links proliferate and potential points of attack from the cyber realm are introduced. Technology gaps also exist with respect to safely managing fallback navigation methods for autonomous systems in the event of global navigation satellite system outages or spoofing.

- **Resilience -** advanced aerial mobility systems must be able to maintain required minimal functionality when components of the system suffer degradation or outage and have the ability to efficiently recover from contingency events or situations.

Technical Challenges 3

- **Airspace** - There is a need for flight data gathering and dissemination specific to autonomous system operations, including networked traffic control and micro-weather forecasting and reporting.

- **Flexibility** - Advanced aerial mobility fundamentally expands the viable applications for flight, and many of these applications remain unforeseen. A flexible advanced air mobility system will include a need for flight rules and procedures for routine operation in all classes of airspace as well as for ground operations.

- **Ground Infrastructure -** More ground locations may be served using advanced aerial mobility systems than with airports today. These ground locations will be smaller and far more numerous than airports and will necessarily be more seamlessly combined with other transportation modes and in closer proximity to the general public, less able to partition and segment.

- **Air Vehicles** – Certification rules and methods, software qualification and safety assurance

Barriers to AAM 1

- Collaboration and Government Leadership
  - Overcoming the hurdles will require collaboration between stakeholders from across different areas of specialty, both within and outside traditional aviation. No single entity will solve all the issues ahead. Government and private sectors will have to coordinate closely to enable each other and to achieve progress.

- Societal Acceptance
  - Perception that the benefits it delivers outweigh the impacts it has on bystanders, the environment, and overall quality of life
  - Environmental factors such as noise and visual annoyance from air
  - Debates over privacy have impacted progress in early applications, including drones, resulting in a patchwork of regulations, making expansion of advanced aerial mobility difficult.

Barriers to AAM 2

- Clear, Supportive Regulations
  - Advanced aerial mobility brings changes to the assumptions under which today's regulatory function evolved under and with it requires a new way that the regulatory function must work.
  - New technologies must find a way to be certified. New, diverse, and constantly evolving applications of flight will displace the gradual evolution of commercial aviation.
  - A new certification construct could greatly improve advanced air mobility market participation by these new, especially non-aviation, entrants, though it must be designed so that current safety standards are maintained within these new platforms.
  - These changes to enable advanced aerial mobility cannot occur on their own and cannot be accomplished by a single party—not even a regulator with the authority to do so.

Barriers to AAM 3

- Environment
  - Being able to communicate a vision that squarely addresses societal benefits is critical to successful implementations of advanced air mobility.
  - It is important to understand the direct environmental impact characteristics of advanced air mobility vehicles. It is just as important to understand the public reaction to these technologies.

- Economy
  - Most, if not all, of the economic concerns relate to the scalability of advanced aerial mobility operations. Business case closure will be largely dependent on the cost associated with solving the above barriers and bringing cost to the consumer in line with traditional modes of ground-based transportation.