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Reimagining the Future of Transportation with Personal Flight: Preparing and Planning for Urban Air Mobility

Authors
Cohen, Adam
Guan, Justin
Beamer, Matthew
et al.

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Reimagining the Future of Transportation with Personal Flight

Preparing and Planning for Urban Air Mobility

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Adam Cohen
Justin Guan
Matthew Beamer
Ryan Dittoe
Seyedmirsajad Mokhtarimousavi

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Unpublished Workshop
Summary

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Common Terms

The following terms are frequently used in this document.

Automating Dependent Surveillance-Broadcast (ADS-B) is a surveillance technology in which an aircraft determines its position via satellite navigation and periodically broadcasts it, enabling it to be tracked.

Electric Vertical Take-off and Land (eVTOL) is an electric propelled aircraft that can hover, take off, and land vertically.

Federal Aviation Administration (FAA) is a governmental body of the United States with powers to regulate all aspects of civil aviation in that nation as well as over its surrounding international waters.

Federal Aviation Regulations (FARs) are rules prescribed by the Federal Aviation Administration (FAA) governing all aviation activities in the United States. The FARs are part of Title 14 of the Code of Federal Regulations (CFR).

Mobility on Demand (MOD) is a concept based on the principle that transportation is a commodity where modes have distinguishable economic values. MOD enables customers to access mobility, goods, and services on demand.

National Aeronautics and Space Administration (NASA) is a U.S. government agency responsible for the civilian space program, as well as aeronautics and aerospace research.

National Transportation Safety Board (NTSB) is an independent U.S. government investigative agency responsible for civil transportation accident investigation.

Part 135 Operations refers to a chapter in the FARs that regulates primarily charter and air taxi operations and sets the requirements for the persons and aircrafts performing on-demand and commuter operations.

Rural Air Mobility (RAM) is an emerging concept envisioning a safe, efficient, accessible, quiet, and multi-use air transportation system for passenger mobility and cargo delivery within or traversing rural and exurban areas.

Shared Micromobility is an innovative transportation strategy enabling the shared use of a bicycle, scooter, or other low-speed mode on an as-needed basis.

Small Unmanned Aircraft is an unmanned aircraft weighing less than 55 pounds on takeoff, including everything onboard and attached to aircraft. Small unmanned aircraft are commonly referred to as a “drones.”

Transportation Network Companies (TNCs) provide prearranged and on-demand transportation services for compensation in which drivers of personal vehicles connect with passengers. Digital applications are typically used for booking, electronic payment, and ratings.

Unmanned Aircraft (UA) is an aircraft operated without the possibility of direct human intervention from within or on the aircraft (14 CFR 107.3).

Unmanned Aircraft System (UAS) is an unmanned aircraft and associated elements, including communication links and the components that control the unmanned aircraft, that are required for the pilot in command to operate safely and efficiently in the national airspace system.

Unmanned Aircraft System Integration Pilot Program (UAS IPP) is a Federal Aviation Administration pilot program intended to test and accelerate the safe integration of unmanned aircraft systems into U.S. airspace.

Urban Air Mobility (UAM) is an emerging concept envisioning a safe, efficient, accessible, quiet, and multi-use air transportation system for passengers and cargo within or traversing metropolitan areas.

Unmanned Aircraft System Traffic Management (UTM) is a traffic management ecosystem for uncontrolled operations that is separate from, but complementary to, the FAA's Air Traffic Management (ATM) system. UTM development will ultimately identify services, roles and responsibilities, information architecture, data exchange protocols, software functions, infrastructure, and performance requirements for enabling the management of low-altitude uncontrolled drone operations.

Vertical Take-off and Land (VTOL) is an aircraft that can hover, take off, and land vertically.

Executive Summary

Urban Air Mobility (UAM) is an emerging concept envisioning a safe, efficient, accessible, quiet, and multi-use air transportation for passenger mobility, cargo delivery, and emergency management within or traversing a metropolitan area. Urban air mobility is part of the U.S. Department of Transportation's broader vision for Mobility on Demand (MOD), an innovative transportation concept evolving around connected travelers, where consumers can access mobility and goods delivery services on demand by dispatching or using urban aviation services, courier services, shared automated vehicles, shared mobility, public transportation, and other innovative and emerging transportation technologies. In recent years, several companies have designed and tested enabling elements of the UAM concept including; prototypes of vertical take-off and landing (VTOL) capable aircraft, operational concepts, and market studies to understand potential business models. While UAM may be enabled by the convergence of several factors, several challenges such as: community acceptance, safety, equity, issues around planning and implementation, airspace, and operations, could create barriers to mainstreaming.

UAM may serve a variety of use cases including: disaster relief, goods delivery, and passenger mobility and has the potential to:

- Create additional mobility and delivery options by utilizing low altitude airspace for additional urban transportation capacity;
- Reduce journey times for travelers by flying over ground congestion using more direct routing between origins and destinations;
- Expand access to goods delivery, particularly in remote locations; and
- Support emergency management missions, such as air ambulance, emergency supply delivery, organ transport, and search and rescue operations.

Other popular terms include Rural Air Mobility (RAM)[1], Advanced Air Mobility (AAM), and Part 135 operations[2] (referring to the Federal Aviation Administration rules for commuter and on-demand operations).

On January 12, 2020, the Transportation Research Board (TRB) of the National Academies hosted a workshop titled "Reimagining the Future of Transportation with Personal Flight: Preparing and Planning for Urban Air Mobility" at the 99th Annual Meeting of the Transportation Research Board in Washington, D.C. The workshop was sponsored by the following stakeholders:

- Aviation Group (AV000)
- Young Members Council - Aviation (AV000(1))
- Standing Committee on Intergovernmental Relations in Aviation (AV010)
- Standing Committee on Aviation System Planning (AV020)
- Standing Committee on Environmental Impacts of Aviation (AV030)

[1] An emerging concept envisioning a safe, efficient, accessible, quiet, and multi-use air transportation system for passenger mobility, cargo delivery, and emergency management within or traversing rural and exurban areas.
[2] The Federal Aviation Regulations, or FARs, are rules prescribed by the Federal Aviation Administration (FAA) governing all aviation activities in the United States. The FARs are part of Title 14 of the Code of Federal Regulations (CFR). Part 135 is a chapter in the FARs that regulates primarily charter and air taxi operations and sets the requirements for the persons and aircrafts performing on-demand and commuter operations.

- Standing Committee on Aviation Economics and Forecasting (AV040)
- Standing Committee on Airport Terminals and Ground Access (AV050)
- Standing Committee on Airfield and Airspace Capacity and Delay (AV060)
- Subcommittee on Unmanned Aircraft Systems (UAS) (AV060(1))
- Standing Committee on Aircraft/Airport Compatibility (AV070)
- Standing Committee on Light Commercial and General Aviation (AV080)
- Standing Committee on Aviation Security and Emergency Management (AV090).

Organization of this workshop was made possible by the sponsors and the organizing committee members: Adam Cohen, Innovative Mobility Research, UC Berkeley; Justin Guan, Arup; Matthew Beamer, Cambridge Systematics; Ryan Dittoe, Sacramento County Department of Airports; and Seyedmirsajad Mokhtarimousavi, Florida International University. The Organizing Committee would like to acknowledge all of the efforts to support the workshop by the aviation group chair David Ballard, aviation committee chairs, and Christine Gerencher, Senior Program Officer-Aviation and Environment of the Transportation Research Board.

The workshop facilitated a dialogue among over 130 participants from public-sector organizations, private companies, non-governmental organizations, and educational institutions. Government, industry, and academic thought leaders presented and participated in panel discussions with the audience about opportunities and challenges, planning issues, community acceptance, research, and next steps needed for implementation, emphasizing the future of multimodal UAM. In the second half of the workshop, attendees participated in interactive breakout sessions and reported back on next steps for research needed to guide the safe, sustainable, and equitable implementation of UAM. The workshop emphasized the role of safety, community acceptance, multimodal vertiport infrastructure, and automation shaping the future of UAM.

The workshop addressed several key goals:

- Presenting on the latest developments from industry and academic research;
- Discussing the role of UAM and how it may affect urban transportation and planning;
- Opportunities and challenges that arise when planning for UAM at the local and regional level;
- Highlighting the role of vertiports and the importance of first- and last- mile connections to UAM;
- Discussing airspace and unmanned traffic management needs;
- Best practices and guiding principles to guide the safe, equitable, and sustainable implementation of this new transportation mode; and
- Developing a research agenda to support the equitable and sustainable implementation of UAM.

The workshop focused on many new UAM developments. The role of electrification, automation, and unmanned traffic management were discussed in a variety of contexts and how these innovations could make UAM more affordable and economically viable. Key insights and discussion points from the workshop include the following:

1. **Safety should be the top priority for all stakeholders.** The public and private sectors should initiate a multi-national vision zero UAM safety project. Vision zero aims to achieve and maintain an urban air mobility system with no fatalities and serious injuries involving VTOL and urban flight.

2. **Technology is innovating faster than the regulatory environment.** Both the regulatory environment and air traffic management will need to quickly evolve to prevent similar disruptions associated with transportation network companies (TNCs) and shared micromobility (bikesharing and scooter sharing). The disruption of urban surface transportation, where providers initiate service without regulatory approval should not be permitted in urban airspace. Additionally, the Federal Aviation Administration (FAA) has maintained a long-standing position that federal preemption of airspace regulation is paramount to a safe national airspace system. However, local and regional governments confronted with the potential of UAM services may argue for more local control over when and where urban aircraft fly. The regulatory environment will need to quickly adapt to new aviation technologies (e.g., electrification and automation) as well as new users of airspace, such as urban and rural air mobility.

3. **There are numerous barriers to community acceptance that need to be overcome.** Potential community concerns include noise and visual pollution, privacy (particularly for flights over residential land uses), equity (that UAM is not just a mode for the wealthy to buy their way out of congestion), personal safety, airworthiness of small aircraft, electric aircraft range anxiety, and apprehension toward autonomous flight.

4. **Many questions remain about serving a variety of underserved communities, such as low-income households and people with disabilities.** Numerous panels expressed concerns that UAM may increase inequality with only the wealthiest households will have access to air taxi service. Panelists also emphasized the need to ensure that UAM is accessible for people with disabilities and other users with special needs.

5. **More research on the sustainability of urban air mobility is needed.** Numerous panelists discussed the lack of research and understanding about the environmental, travel behavior, lifecycle, and surface transportation network effects of UAM. Key research gaps identified include:

- How will travelers' access vertiports, both from their origin and to their destination?
- How many gas-powered vehicles could UAM remove from the road?
- Will UAM remove enough vehicles from the surface transportation network to make a noticeable impact on congestion? If so, will UAM induce demand due to reduced travel times or encourage more people to drive (due to reduced congestion from travelers switching to UAM)?
- What are the lifecycle emissions impacts associated with UAM compared to other modes of transportation?

The interactive townhall discussion provided an opportunity for the audience to get directly involved with the moderators after listening to the four sessions. A vibrant discussion ensued on thoughts for the evolution of UAM; policy challenges and needs; barriers to community acceptance; potential strategies for overcoming key challenges; and research needs for maximizing opportunities and mitigating key risks to prepare for UAM. Participants emphasized the need for greater TRB involvement and support for research on UAM. Key research needs identified include:

- Studying the environmental impacts of UAM implementation and policies to support sustainability;
- Understanding how to integrate UAM and small unmanned aircraft systems (UAS) (i.e., drones) into the same airspace and traffic management system;
- Researching the safety and health impacts of UAM (including personal safety on-board autonomous aircraft, such as crime);
- Identifying data needs, including data metrics, data formats, and standards for sharing;

- Modeling the potential traffic and land use impacts of UAM on the community;
- Understanding the flight path profiles of innovative aircraft and if traditional helipad approach paths need to be adapted or changed;
- Researching public perception of aviation technologies, such as the issues associated with electric range anxiety, willingness to fly on autonomous aircraft, etc.;
- Identifying best practices for multimodal integration and vertiport design; and
- Studying the equity and economic impacts of UAM on communities (e.g., opportunities for increased employment, reduced ground vehicle traffic, accessibility of UAM by disadvantaged communities and users with special needs).

Workshop Overview

This workshop synopsis covers findings and discussions from the event and summarizes the key topics explored throughout the day. The workshop commenced with introductions from the day's facilitators: Justin Guan of Arup and Adam Cohen of Innovative Mobility Research (IMR) at the University of California, Berkeley (UC Berkeley), and participant introductions. Susan Shaheen of UC Berkeley assisted with the preparation of this e-summary.

Following participant introductions, the workshop included an introductory presentation by Cohen, four expert panel sessions, and a spotlight presentation by Davis Hackenberg of the National Aeronautics and Space Administration (NASA). Key points made by each panel are summarized below. Next, this circular summarizes findings from the interactive townhall session. As part of this interactive discussion, participants were divided into three groups with a facilitated discussion intended to probe the potential evolution of urban air mobility (UAM), use cases, public policy, community acceptance, and research needs. Finally, this summary presents closing thoughts and key takeaways from the workshop. The workshop agenda is also provided, along with copies of the slides presented, along with key takeaways.

Speakers and Panel Sessions

WORKSHOP OVERVIEW AND PARTICIPANT INTRODUCTIONS

The workshop started with an overview by Cohen and Guan. Both set the stage for the day by presenting an overview of the agenda focusing on opportunities, challenges, and community acceptance of UAM in the morning and pivoting to issues around planning, implementation, airspace, and operations in the afternoon.

OPENING PRESENTATION: URBAN AIR MOBILITY: HISTORY, NUTS AND BOLTS, AND THE CURRENT STATE OF THE INDUSTRY

Cohen opened the workshop with an overview of urban air mobility, including terms and definitions; a taxonomy of urban air mobility; history and evolution of the UAM concept; and long-range planning considerations. He started by introducing NASA's vision for UAM by *"revolutionizing mobility around metropolitan areas by enabling a safe, efficient, convenient, affordable, and accessible air transportation system for passengers and cargo."* Cohen then discussed the importance of standard terms and definitions for UAM. He emphasized that legal definitions for urban air mobility are necessary to foster consumer education and outreach, mainstream services, expand opportunities for public-private partnerships, guide public policy, and international harmonization of regulations. He emphasized the need for public agencies and industry associations to work together to develop clear, concise, and uniform definitions. Cohen then discussed his efforts with SAE International, a global mobility standards organization, to co-sponsor JA3163 that includes standard terms and definitions for UAM and rural air mobility (RAM).

Cohen then introduced a taxonomy of urban air mobility services, including a combination of piloted, partially automated, and fully autonomous passenger aircraft. He also discussed a variety of piloted, partially automated, and fully autonomous roadable aircraft - aircraft that can also be driven as vehicles - that are currently under development. He explored s other developments in the industry pertaining to urban goods delivery, such as aerial warehousing, unmanned aircraft systems (also known as UAS and drones), United Parcel Service's prototype that pairs drone delivery with a delivery truck. Cohen also provided a history and timeline of UAM aircraft development beginning in the early 1900s and early UAM passenger services using helicopters beginning in the 1950s. Pivoting toward long-range planning considerations, Cohen then discussed the concept of the UAM complete trip and the need for service providers to consider planning and booking travel, first- and last- mile connections to a range of take-off and landing infrastructure (vertipads, vertiports, and vertihubs), and arrival at a traveler's destination. He also explored the role of the built environment and the need to tailor planning considerations, land use policy, infrastructure, and UAM use cases to an array of urban contexts. Cohen further discussed a number of potential concerns with UAM, such as equity, accessibility for people with disabilities, affordability, aesthetics, noise pollution, privacy over residential areas, and potential societal concerns with remotely piloted and autonomous operations. Cohen briefly discussed the results of one NASA market study on UAM. Cohen introduced the newly formed Community Air Mobility Initiative (CAMI), a nonprofit organization dedicated to supporting the responsible integration of UAM at the state and local levels of government. He discussed the importance of UAM research including: 1) the need to develop data metrics, models, planning platforms, and methodologies to assess the economic and travel impacts of UAM; 2) longitudinal tracking and forecasting of modal impacts as services come online; 3) the need for public agencies to forecast and evaluate the impacts of UAM/UAS pilot projects and guide public policy development; and 4) developing public policy that supports seamless multimodal integration and balances data sharing with privacy (user, private companies, and public agencies). Cohen concluded by discussing key questions asked by policymakers and the media about UAM, the importance of standardizing data collection, and the critical need to conduct UAM pilots and evaluations to enhance understanding of key opportunities and challenges. Cohen's slides are available at the end of this e-summary.

PANEL SESSION 1: POTENTIAL OPPORTUNITIES AND CHALLENGES OF URBAN AIR MOBILITY

The first panel of the morning, moderated by Cohen, discussed potential opportunities and challenges that may arise when preparing, planning, and implementing UAM from a variety of public and private sector perspectives. This panel included four expert panelists: Christopher Hart, Hart Solutions LLC; Jim Herrera, FAA; Bill Goodwin, Joby Aviation; and Tom Gunnarson of Wisk. Cohen opened the panel by asking panelists *"What do you envision are the top opportunities and challenges for urban air mobility over the next 3 to 5 years?"* Panelists expressed optimism that there would be a number of electric, vertical, take-off and land (eVTOL) aircraft certified over the next few years, and eVTOL air taxi service would be launched in a handful of cities across the globe. Panelists generally felt that small city-states were likely to be the earliest adopters of UAM using eVTOL aircraft due to simplified governance structures that may simplify early operations. Panelists also expressed a number of concerns, emphasizing potential challenges associated with community acceptance and equity. Panelists discussed the potential for community opposition among non-users who may be concerned about privacy, noise, and visual pollution associated with increased urban air traffic and low-level flight over communities. A few panelists also highlighted equity concerns with the high cost of piloted UAM services. Panel members acknowledged that although commercial aviation is now generally accessible to most households, it took decades for the industry to achieve mass market affordability.

Hart, former chairman of the National Transportation Safety Board (NTSB), emphasized the importance of safety and consumer expectations that UAM will be equally as safe or safer than commercial aviation. Panelists discussed a number of safety challenges, such as the potential for congested airspace, and high volumes of flight activity both at low altitudes and over populated areas. Panelists also discussed the potential technical challenges and societal acceptance of autonomous flight operations, such as cyber security and consumer willingness to fly in an aircraft without a pilot. Jim Herrera, UAM program manager for the FAA discussed the multiple paths to aircraft certification. The traditional Part 21.17(a) method can be used for aircraft that fall within existing categories. Additional requirements and special conditions may apply. For aircraft that do not fall into existing categories, Part 21.17(b) may be used. However, this path is not meant for mass production, so eventually an update to the regulatory framework may be needed for large-scale UAM deployments for aircraft that take this path. As the UAM marketplace grows, panelists emphasized the potential for regulatory reform to enable mass-market certification of aircraft and air taxi operators (i.e., commuter and on-demand operations). In addition to discussing aircraft and air carrier certifications, panelists also explored opportunities and challenges of airspace regulation. Bill Goodwin, Deputy General Counsel of Policy and Regulatory Affairs at Joby Aviation noted an article he had previously published discussing the potential role of local governments in low-altitude airspace regulation. Goodwin emphasized the need for a new paradigm in a future of low-altitude airspace management that recognizes the complementary roles of both local and federal governments and the unique capacity for unmanned traffic management (UTM) technology to facilitate stakeholder roles.

Panelists emphasized that VTOL is still under development and the critical importance for TRB to support research on UAM to help advance the industry and overcome key challenges. Cohen concluded the panel by asking: "*What do you think the industry will look like in 10 years?*" Highlighting differences between the public and private sectors, panelists representing aircraft manufacturers (Goodwin and Gunnarson) expressed optimism about the growth potential of the UAM market looking forward to 2030. In contrast, panelists with public sector expertise were generally more cautiously optimistic, emphasizing the difficulty public agencies have keeping pace with private-sector innovations. The panel concluded by emphasizing that there would likely be a lot of experimentation and lessons learned, as the operators, manufacturers, and use cases for UAM evolve over the next decade.

SPOTLIGHT SESSION: NASA ADVANCED AIR MOBILITY (AAM) RESEARCH

Davis Hackenberg of NASA's Advanced Air Mobility initiative focused on innovative, emerging, and transformational aviation technologies. Hackenberg provided background on NASA's unmanned aircraft systems (UAS) traffic management (known as UTM) initiatives, urban air mobility research, and the formation of NASA's UAM coordination and assessment team comprised of a variety of subject matter experts across NASA's mission directorate. He briefly provided background on two UAM market studies (by McKinsey & Company and Booz Allen Hamilton), both funded by NASA to understand potential market opportunities and challenges. Hackenberg emphasized the need to include all UAM stakeholders and introduced NASA's vision to transform mobility around metropolitan areas by enabling a safe, efficient, convenient, affordable, and accessible air transportation system for passengers and cargo. To illustrate the potential impacts of UAM on mobility and the built environment, Hackenberg showed a map of the Washington D.C. metropolitan area with 60-minute weighted average commute times and compared it to an approximate range for a 30-minute flight time using UAM (approximately a 75-mile radius). Using this hypothetical example, UAM has the potential to expand the District of Columbia metropolitan area as far as Lancaster, PA; Harrisburg, PA; and

Richmond, VA. Hackenberg also discussed NASA's Urban Air Mobility Grand Challenge, which aims to improve UAM safety and accelerate scalability through integrated demonstrations by hosting a series of UAM ecosystem-wide challenges beginning in 2020. The UAM Grand Challenge will support the FAA in developing an approval process for UAM vehicle certification, develop flight procedure guidelines, evaluate communication, navigation and surveillance requirements, define airspace operations management activities and characterize vehicle noise levels. The first testing opportunity in the Grand Challenge series will focus on the developmental testing of U.S. developed aircraft and will include airspace operations management services to explore architectures and technologies needed to support future safety and scalability of UAM operations. The UAM Grand Challenge is structured to work with the UAM community to identify and address the key challenges to achieving NASA's vision for urban air mobility. Hackenberg's slides are available at the end of this e-summary.

PANEL SESSION 2: COMMUNITY ACCEPTANCE & PUBLIC PERCEPTION

The second panel session of the morning, moderated by Matthew Beamer of Cambridge Systematics, consisted of a discussion of public perception and community acceptance of UAM. This included six expert panelists: Rohit Goyal, Uber; Mary Ellen Eagan, HMMH; Daniel Friedenzohn, Embry-Riddle Aeronautical University; Paul Wheeler, Utah Department of Transportation (UDOT); Michael Doty, NASA; and Chrishanth Fernando.

After introducing the panelists, Beamer opened by asking the panel what they thought the notable concerns were associated with UAM that could influence community acceptance. Wheeler of UDOT said that while there is a lot of concern with urban air mobility, when you look at modal safety records aviation has a better safety record than a private vehicle. He emphasized the importance of the industry in conveying this message to the public. Goyal noted, however, that the public may feel more in control in a vehicle because it is on the ground than in aircraft 1,000 to 2,000 feet above the ground if an emergency were to occur.

Fernando discussed a study completed by the Booz Allen Hamilton team for NASA that looked at community acceptance from the perspective of users and non-users. Fernando also emphasized the importance of leveraging UAM for emergency response and humanitarian use cases to build public trust. Fernando also said that while weather could pose a technical barrier to entry, weather is also likely to pose a barrier to public acceptance. Goyal noted the importance of safety first and said that no stakeholder in the industry should fly an aircraft that has not been demonstrated to be safe. Goyal pointed out that unlike commercial aviation where people generally do not have a mode choice for long-distance travel, the consumer has lots of choices for urban and regional travel. Thus, UAM must focus on providing a great customer experience. Goyal emphasized the need to focus on aircraft noise (both individually and scaled UAM operations with many aircraft operating simultaneously) and overcoming perceptions in the early phases of VTOL deployments that UAM is a niche market. Goyal discussed the need to emphasize the goal is to make UAM an accessible service available to a mass market. Eagan also raised the issue of equity, and timing of services and consumer pricing could have a notable impact on public perception. She said that if the services operate for extended periods serving a fraction of the wealthiest one percent, UAM could have difficulty gaining community acceptance. As such, making UAM more affordable and equitable could be key in helping to gain public acceptance. She also emphasized the importance of focusing on environmental sustainability. Wheeler also noted the potentially close relationship between UAM and local zoning, such as flights over residential areas that could impact public perceptions.

Beamer asked the panel if there were lessons learned from other areas of aviation that could be applied to UAM with respect to community acceptance. Friedenzohn discussed examples from UAS integration where the FAA and other stakeholders have done a good job engaging communities through open houses to introduce the public to this emerging technology. Eagan noted the integration of performance-based navigation into the national airspace system presented an opportunity to engage the community and that the FAA has improved community education and outreach. Doty discussed a study completed at NASA Langley that compared UAS/drone noise, cars, and other ambient noise. Doty emphasized the importance of not just considering the volume of noise but also other sound characteristics that could be disruptive. The study concluded that a vehicle could be a lot louder but have the same annoyance to the public as UAS/drone operations. Doty also emphasized the importance of psychological factors and that noise that is recognizable may be less disruptive than a noise that cannot be easily identified. Eagan also noted that the attitude toward the source of the noise can also impact public perception of that noise. Fernando emphasized that in the future with automated and electric vehicles, ambient noise could be quite different and possibly quieter thereby making UAM more perceptible and possibly more disruptive to some people. Fernando also discussed the importance of continuing to reduce UAM noise as the transportation ecosystem evolves over the coming decades.

Panelists also explored the potential of autonomous flight and community acceptance. Generally, panelists agreed that there are notable barriers of trust and confidence in aircraft autonomy before users and non-users would likely accept pilotless UAM aircraft flying over communities. Goyal noted the importance of gaining community buy-in for UAM first and then building public acceptance for autonomous operations over time. Goyal compared UAM to the advent of elevators where early deployments had elevator operators open and close the doors, greet guests, and address any concerns. In response to an audience question, Goyal concluded by saying that community acceptance may be contingent upon total travel time. He emphasized the importance of accounting for total UAM travel times, including first- and last- mile connections to vertiports when considering the societal impacts.

PANEL SESSION 3: ISSUES AROUND PLANNING AND IMPLEMENTATION

In the afternoon, panel members discussed issues related to planning and implementation. Many issues were covered, such as multimodal integration, land use, and the roles of the public and private sectors. This panel was moderated by Justin Guan of Arup and included five experts: YuYu Zhang, University of South Florida; Ric Stephens, WHPacific Inc.; Greg Bowles, Joby Aviation; Ghassan Khankarli, City of Dallas Department of Transportation; and Fred Judson, Ohio Department of Transportation.

Judson, UAS Director of the UAS Center at the Ohio Department of Transportation (ODOT) discussed Ohio's interest in how state DOTs can potentially leverage the same digital infrastructure used by connected and automated vehicles for UAS and UAM. Judson also said that ODOT is interested in understanding the potential economic impacts of UAM to the state of Ohio. Stephens of WHPacific discussed potential scenarios for air traffic management and operations in the future. One scenario is that there are separate systems for UAS, UAM, and commercial air carriers that are not fully integrated. He discussed how the National Airspace System is headed toward a very fragmented approach with the roll out of automatic dependent surveillance-broadcast (more commonly known as ADS-B) for aircraft and separate remote IDs for unmanned aircraft systems, such as drones. Another scenario he discussed is a more integrated approach. He expressed the importance of integrated long-range planning that incorporates commercial aviation, general aviation, UAM, and UAS.

Ghassan Khankarli from the City of Dallas emphasized that when discussing system integration, stakeholders should not just refer to airspace integration but should also include the physical infrastructure needed to support UAM and other modal connections needed to support air taxis. Khankarli also discussed a variety of local regulatory and policy issues that could emerge with UAM, such as land use, zoning, liability, and others. Khankarli further explored the need to understand the impacts of UAM on the electric grid, plan for electric charging, and integrate UAM into continuity of operations and disaster planning in the event of an emergency (i.e., tornados, etc.). Khankarli noted the importance of social and community impacts, including equity and workforce development. He emphasized the need to ensure UAM is accessible for people with disabilities and preparing the workforce for UAM pilots, mechanics, airspace managers, and other related specialties. Khankarli concluded with a discussion of institutional readiness, the importance of making data-driven policy decisions, and the need for enhancing communication with a variety of internal municipal departments and external stakeholders.

Guan asked panelists how UAM would impact urban planning, land use, and development, and the types of planning considerations for landing sites in urban environments. Khankarli discussed the importance of connecting vertiports and the convention center to a planned Dallas-Houston high-speed rail station using automated shuttles. Stephens explored three key milestones for UAM over the coming decades. The first milestone he described was initial UAM operations or regularly scheduled "air shuttle services" along specific air routes (e.g., between an airport and downtown) that could be operational by 2028. The next milestone requiring increased infrastructure investments is "air metro services," which would include multiple flights between numerous vertiports in an urban area. The final milestone he described was "air taxi services" that would provide on-demand, very decentralized services using numerous vertipads and small vertiports dispersed throughout a region. He said while some say that people may not want to live near vertiports due to noise or other impacts, he believes that people will want to locate near UAM infrastructure because they will be destinations that encourage mixed-use development (similar to transit-oriented development around a rail station). He said UAM should be viewed as a tool for cities to encourage and guide development. He also explained how rural air mobility will likely have very different impacts than urban air mobility. Judson also emphasized the importance of identifying existing infrastructure and understanding how it could be repurposed with minimal physical modification; renovated and adapted; or replaced and redeveloped to incorporate UAM.

YuYu Zhang of the University of South Florida emphasized the importance of high-density and mixed-use development around mobility hubs. She said that UAM creates an opportunity to connect transit-oriented/vertiport-oriented communities. She also pointed out that some land owners are being approached by UAM service providers and infrastructure developers, raising a question about whether the infrastructure should be exclusive to a single service provider. She said that publicly funded infrastructure could ensure access to vertiports by multiple UAM service providers (e.g., similar to airports) whereas privately funded infrastructure may be faster to fund and construct.

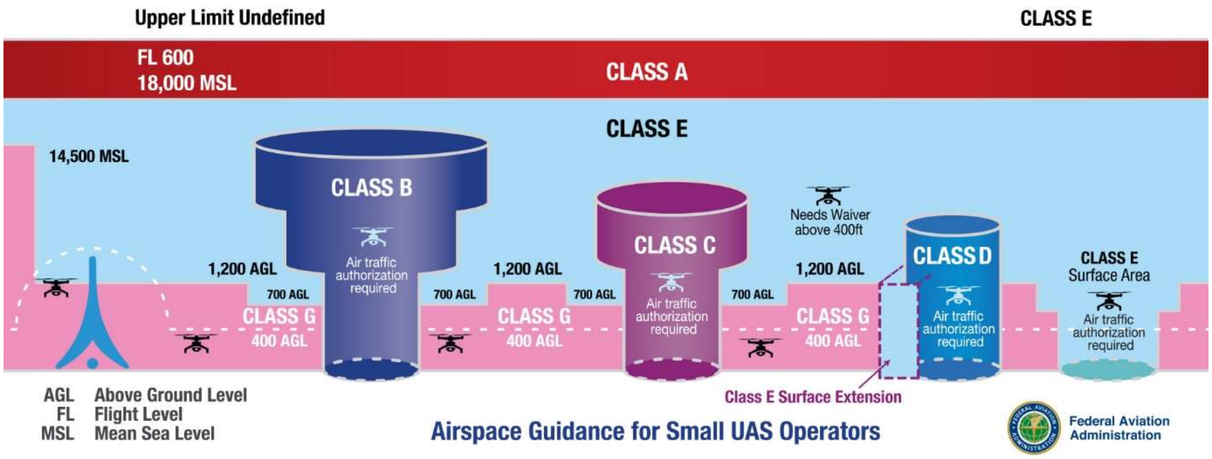
Bowles of Joby Aviation discussed the importance of the customer experience and reducing wait times when changing between modes and UAM. He gave the example of the typical thought process and the steps that airline passengers go through that contribute to a poor customer experience (e.g., long waits at security, long walks to the gate, long walks between arrivals and the Lyft/Uber pick-up, etc.). He emphasized that a key difference with UAM (compared to commercial aviation) is that it is going to interface with the surface in new locations, which raises a lot of new questions. He emphasized the importance of stakeholder engagement to identify, understand, and mitigate potential concerns as UAM emerges in the marketplace. Participants asked a few questions about the impacts of UAM on the power grid. Bowles responded by saying that the aircraft Joby is developing will have similar impacts to that of the Tesla supercharger on the grid. He emphasized that the electrification of aviation will have larger impacts on the grid as larger commercial aircraft begin to electrify. He said he anticipates an overall rise in power consumption due to the electrification of the entire transportation ecosystem, but that the peak capacity could be managed through ground battery storage to help flatten out demand on the power grid.

PANEL SESSION 4: AIRSPACE SYSTEM AND OPERATIONAL CHALLENGES

In the last panel session, experts highlighted the role unmanned traffic management, airspace systems, and other operational challenges. Moderator Ryan Dittoe of the Sacramento County Department of Airports opened the session introducing six panel members: John Robbins, Embry-Riddle Aeronautical University; Byron Thurber, Arup; Ella Atkins, University of Michigan; Jim Gregory, Ohio State University; Chris Metts, Deloitte; and Darshan Divakaran, North Carolina Department of Transportation (NCDOT).

Dittoe opened by asking panelists their thoughts on the most notable airspace systems and operational challenges. Atkins of the University of Michigan emphasized the importance of resilient, secure, and redundant data link. Data link is a form of communication used to send information between aircraft and air traffic controllers when an aircraft is too far from the ATC to make voice radio communication and radar observations possible. She emphasized that the industry cannot rely on voice communications for a variety of reasons (i.e., delay transmitting, interpreting and responding to transmissions; difficulty hearing transmissions; etc.). She said that the transition from voice to data link will be difficult due to current regulations, stakeholder preferences, and cybersecurity concerns. Divakaran of NCDOT said one of the challenges will be redefining the airspace for a growing number of users. He also discussed challenges with beyond visual line of sight operations for UAS. He discussed how the FAA's UAS Integration Pilot Program (IPP) has begun to explore these issues but that more work is needed. FAA's UAS IPP is helping the USDOT develop new rules that support more complex low-altitude operations by: 1) identifying ways to balance local and national interests related to drone integration; 2) improving communications with local, state and tribal jurisdictions; 3) addressing security and privacy risks; and 4) accelerating the approval of operations that currently require special authorizations. IPP has created a meaningful dialogue on the balance between local and national interests related to drone integration and provides actionable information to the USDOT on expanded and universal integration of drones into the National Airspace System. The IPP has funded eight lead participants that are evaluating a host of operational concepts including: package delivery, flights over people and beyond the pilot's line of sight, night operations, detect-and-avoid technologies, and the reliability and security of data links between pilot and aircraft. Divakaran noted that while the IPP has started this conversation, the industry still has not perfected the integration of unmanned systems for small unmanned aircraft (aircraft that weigh less than 55 pounds on takeoff) nor large UAS into routine operations. He emphasized that although people tend to talk about UAS and UAM as the same thing, the operational airspace really needs to be redefined because small UAS is generally limited to under 400 feet, while UAM will operate at a higher altitude (See Figure 1).

Figure 1. Airspace Guidance for Small UAS Operators



Source: Federal Aviation Administration

Gregory of Ohio State University added that a fundamental challenge is taking innovative and emerging aviation technologies and integrating them into an existing, antiquated, and analog system. As such, there is an inherent tension between the airspace system we have today and the technology-enabled airspace system we would like to have. He said the principal challenge is understanding how to design a system that leverages the latest innovations, while making it backward compatible accommodating analog voice or crop dusters that do not have many systems on-board. Metts from Deloitte emphasized that the pace of technology advancement is making it difficult for regulators to keep up. Robbins of Embry-Riddle Aeronautical University discussed multiple challenges that need to be overcome, such as systems integration, data management, regulatory policy, and pilot/operator training.

Dittoe asked the panel about common misperceptions about airspace operations and how this may affect the public. Thurber of Arup explained that there are a lot of flight characteristics that are still unknown that could impact departure and final approach airspace operations, such as whether all VTOL aircraft will be able to hover in place similar to rotorcraft. He explained that many people have a misunderstanding about helicopter operations taking off and landing vertically where in fact rotorcraft still come in on a final approach path. Thurber explained that because of the departure and approach path requirement, helipads actually require clear airspace in two directions. A key question Thurber raised is: “who has the rights to the airspace next to a skyport as a UAM infrastructure network is built?” Atkins said that cybersecurity is often used to cause fear among the aviation community. She said that redundancy can dramatically reduce cyber security risks, and even jamming could impact voice communications. She emphasized that the cost and complexity of data link is not as bad as some people perceive. Gregory added that two common public misconceptions are: 1) an aircraft prototype will be available for flight right away, and 2) UAM will be pilotless or fully autonomous. He said there will likely be a lot of experience with piloted UAM operations before removing the pilot. Atkins respectfully disagreed and emphasized the importance of overcoming the notion that UAM evolves from piloted aircraft with incremental changes. She said that it is entirely possible for UAM to evolve from unmanned operations. Metts also noted that in Deloitte’s work with NASA UAM concept of operations, legacy nomenclature of “IFR,” “airport traffic areas,” and others keep coming up.

He emphasized that the culture of today's aviation continues to be infused into thought processes, and the industry needs to deliberately stop itself and ask "what will be the language and vision of the operation of tomorrow?" Thurber added that another common misperception is that UAM will be able to operate in all conditions. He emphasized that there will be a lot of scenarios (i.e., specific weather conditions) when aircraft will be unable to fly, particularly due to the size and light-weight nature of the aircraft. And, what will be the impacts of these limitations on the market?

Townhall Discussion

After the fourth panel session, the workshop attendees organized into one of three breakout sessions. The Townhall Discussion was conducted at each table by facilitators Guan, Beamer, Dittoe, Cohen, and Seyedmirsajad Mokhtarimousavi who followed a standard protocol intended to probe the following key questions:

1. How do you think UAM will evolve in the future?
2. What use cases or scenarios do you think are likely in the near future with UAM aircraft and services?
3. What is the role of public policy? What policies do you think are needed (or need to be changed) to enable UAM adoption?
4. What is needed to support public acceptance, and prepare the public and private sectors for UAM?
5. What research is needed on UAM? How can TRB help support this research?

After a robust exchange of ideas in the breakout sessions, lead moderators of each breakout reported back on the key ideas that came out of their respective discussions. Participants discussed the likelihood for UAM to serve a variety of use cases employing a combination of piloted and autonomous aircraft in different megaregions across the globe. Some groups highlighted the notable growth potential for urban goods delivery using unmanned aircraft over the next few years. Many groups emphasized the importance of using UAM for emergency response use cases (e.g., air ambulance, search and rescue, firefighting, law enforcement, etc.) to test the technology and build public acceptance. Groups generally agreed that early passenger services would focus on key routes between high-demand nodes, such as urban centers, airports, and stadiums. Many groups highlighted the critical importance of public policy to ensure safety, protect privacy, and guide sustainable and equitable adoption of this emerging technology. Participants also emphasized the importance of clarifying who should regulate and/or protect the airspace around urban vertiports to ensure that building heights do not encroach upon flight departure and approach paths. Participants discussed the need for community engagement to obtain feedback and mitigate any potential adverse impacts. Participants agreed that demonstrating the safety of UAM, mitigating noise, and addressing privacy concerns (e.g., low-level flights over residential neighborhoods) will be key to building public acceptance. A number of participants said it would be easier to build societal acceptance once UAM has operated safely for a few years in several markets.

Participants emphasized the need for greater TRB involvement and support for research on UAM. Key research needs identified include:

- Studying the environmental impacts of UAM implementation and policies to support sustainability;
- Understanding how to integrate UAM and small UAS (i.e., drones) into the same airspace and traffic management system;
- Researching the safety and health impacts of UAM (including personal safety on-board autonomous aircraft, such as crime);
- Identifying data needs, including data metrics, data formats, and standards for sharing;
- Modeling the potential traffic and land use impacts of UAM on communities;
- Understanding the flight path profiles of innovative aircraft and if traditional helipad approach paths need to be adapted or changed;
- Researching public perception of aviation technologies, such as issues associated with electric range anxiety, willingness to fly on autonomous aircraft, etc.;
- Identifying best practices for multimodal integration and vertiport design; and
- Studying the equity and economic impacts of UAM on communities (e.g., opportunities for increased employment, reduced ground vehicle traffic, accessibility of UAM by disadvantaged communities and users with special needs).

Closing Thoughts and Key Takeaways

Guan and Cohen led the closing plenary discussion. Aviation is changing rapidly, and both electrification and automation are likely to enable emerging service and business models, such as urban and rural air mobility that could have a variety of impacts on users, communities, and society.

KEY INSIGHTS

The workshop focused on many of the new developments in UAM. The role of electrification, automation, and unmanned traffic management were discussed in a variety of contexts and how these innovations could make UAM more affordable and economically viable. Key insights and discussion points from the workshop include the following:

1. **Safety should be the top priority for all stakeholders.** The public and private sectors should initiate a multi-national vision zero UAM safety project. Vision zero aims to achieve and maintain an urban air mobility system with no fatalities and serious injuries involving VTOL and urban flight.
2. **Technology is innovating faster than the regulatory environment.** Both the regulatory environment and air traffic management will need to quickly evolve to prevent the disruption caused by TNCs and shared micromobility. The disruption of urban surface transportation, where service providers initiate service without regulatory approval should not be permitted in urban airspace. Additionally, the FAA has maintained a long-standing position that federal preemption of airspace regulation is paramount to a safe national airspace system. However, local and regional governments confronted with the potential of UAM services may argue for more local control over when and where urban air taxis fly. The regulatory environment will need to quickly adapt to emerging aviation technologies (e.g., electrification and automation) as well as new users of airspace, such as UAM and RAM.
3. **There are numerous barriers to community acceptance that need to be overcome.** Potential community concerns that may need to be overcome include concerns about noise

and visual pollution; privacy (particularly for flights over residential land uses); equity (i.e., UAM is not a mode for the wealthy to buy their way out of congestion); personal safety; airworthiness of small aircraft; electric aircraft range anxiety; and apprehension toward autonomous flight.

4. **Many questions remain about serving a variety of underserved communities, such as low-income households and people with disabilities.** Numerous panels expressed concerns that UAM may increase inequality, and only the wealthiest households will have access to air taxi service. Panelists also emphasized the need to ensure that UAM is accessible for people with disabilities and other users with special needs.
5. **More research on the sustainability of UAM is needed.** Numerous panelists discussed the lack of research and understanding about the environmental, travel behavior, lifecycle, and network effects of UAM. Key research gaps identified include:
    - How will travelers' access vertiports, both at their origin and destination?
    - How many gas-powered vehicles could UAM remove from the road?
    - Will UAM remove enough vehicles from the surface transportation network to make a noticeable impact on congestion? If so, will UAM induce demand due to reduced travel times or encourage more people to drive (due to reduced congestion from travelers switching to UAM)?
    - What are the lifecycle emission impacts associated with UAM?

The interactive townhall discussion provided an opportunity for the audience to get directly involved with the moderators after listening to the four sessions. A vibrant discussion ensued on: 1) thoughts for the evolution of UAM; 2) policy challenges and needs; 3) barriers to community acceptance; 4) potential strategies for overcoming key challenges; and 5) research needs for maximizing opportunities and mitigating key risks to prepare for UAM. Many participants expressed the need to improve collective understanding of the potential environmental, travel behavior, social, and land use impacts of UAM and the need for proactive public policy to ensure safe, equitable, and sustainable outcomes. In summary, the workshop facilitated a much-needed dialogue among UAM thought leaders and practitioners from diverse backgrounds and informed the audience about developments, challenges, and the future of on-demand aviation services.

Workshop Agenda

Sunday, January 12, 2020
9:00 a.m. to 4:30 p.m.
Walter E. Washington Convention Center
Washington, D.C.

Sponsored by:
Aviation Group (AV000)
Young Members Council - Aviation (AV000(1))
Standing Committee on Intergovernmental Relations in Aviation (AV010)
Standing Committee on Aviation System Planning (AV020)
Standing Committee on Environmental Impacts of Aviation (AV030)
Standing Committee on Aviation Economics and Forecasting (AV040)
Standing Committee on Airport Terminals and Ground Access (AV050)
Standing Committee on Airfield and Airspace Capacity and Delay (AV060)
Subcommittee on Unmanned Aircraft Systems (UAS) (AV060(1))
Standing Committee on Aircraft/Airport Compatibility (AV070)
Standing Committee on Light Commercial and General Aviation (AV080)
Standing Committee on Aviation Security and Emergency Management (AV090)

Spotlight Theme: "A Century of Progress: Foundation for the Future"

Urban Air Mobility (UAM) is an emerging concept envisioning a safe and efficient system for air passenger and cargo transportation within an urban area, inclusive of small package delivery and other urban Unmanned Aircraft Systems (UAS), which supports a mix of onboard/ground-piloted and increasingly autonomous operations. Technological advances are quickly advancing UAM, and its role as a potential model of transportation is becoming a popular topic of discussion. Recently, several government agencies have recently announced their intention to launch a UAM air taxi service in several cities around the world such as Dallas/Fort Worth, Los Angeles, Melbourne, and Dubai within the next decade. In this workshop, participants will learn about UAM and learn about how to prepare and plan for this new urban mobility technology.

This workshop will feature spotlight presentations and moderated panel discussions of thought leaders (public, private, and academia) in the emerging space of UAM. The program emphasizes technological developments, opportunities and challenges, enabling technologies, equity, and potential societal barriers to implanting UAM. In this panel, participants will learn about:

- What is Urban Air Mobility and how it could impact planning and mobility;
- The opportunities and challenges that arise when planning for Urban Air Mobility at the local and regional levels of governance; and
- Best practices and guiding principles to prepare for this new transportation mode.

In the afternoon, the workshop culminates in an interactive breakout session focused developing a research agenda to guide the development of UAM through one of three breakout groups. The workshop will conclude with a final summary session and closing remarks.

Key goals of the workshop include:

- Presenting on the latest developments in UAM;

- Enhancing public sector preparedness for UAM and UAS technologies;
- Advancing the sustainable and equitable adoption advanced air mobility technologies;
- Highlighting the role of land use, infrastructure, and airspace management;
- Identifying key challenges to adoption and mainstreaming, such as operational challenges and community acceptance; and
- Developing a research agenda to understand and potentially overcome UAM challenges.

Organizers: Adam Cohen, Innovative Mobility Research, UC Berkeley; Justin Guan, Arup; Matthew Beamer, Cambridge Systematics; Ryan Dittoe, Sacramento County Department of Airports; and Seyedmirsajad Mokhtarimousavi, Florida International University.

Workshop Overview & Participant Introductions - 9:00am to 9:05am
Justin Guan, Arup
Adam Cohen, UC Berkeley

Opening Presentation: Urban Air Mobility: History, Nuts and Bolts, and the Current State of the Industry - 9:05am to 9:35am
Speaker: Adam Cohen, UC Berkeley

Session 1: Potential Opportunities and Challenges of UAM - 9:35am to 10:35am
Moderator: Adam Cohen, UC Berkeley
Panelists:

- Tom Gunnarson, Wisk
- Bill Goodwin, Joby Aviation
- Jim Herrera, FAA
- Christopher Hart, Hart Solutions LLC

BREAK: 10:35am to 10:45am

Spotlight Session: NASA Advanced Air Mobility (AAM) Research - 10:45am to 11:00am
Speaker: Davis L. Hackenberg, NASA

Session 2: Community Acceptance and Public Perception - 11:00am to 12:00pm
Moderator: Matthew Beamer, Cambridge Systematics
Panelists:

- Rohit Goyal, Uber
- Mary Ellen Eagan, HMMH
- Daniel Friedenzohn, Embry-Riddle Aeronautical University
- Paul Wheeler, Utah Department of Transportation
- Michael Doty, NASA
- Chrishanth Fernando, Booz Allen Hamilton

LUNCH BREAK: 12:00pm to 1:30pm

Session 3: Issues Around Planning and Implementation - 1:30pm to 2:30pm
Moderator: Justin Guan, Arup
Panelists:

- YuYu Zhang, University of South Florida

- Ric Stephens, WHPacific Inc.
- Greg Bowles, Joby Aviation
- Ghassan Khankarli, City of Dallas Department of Transportation
- Fred Judson, Ohio Department of Transportation

Session 4: Airspace System and Operational Challenges - 2:30pm to 3:30pm

Moderator: Ryan Dittoe, Sacramento County Department of Airports
Panelists:

- John Robbins, Embry-Riddle Aeronautical University
- Byron Thurber, Arup
- Ella Atkins, University of Michigan
- Jim Gregory, Ohio State University
- Chris Metts, Deloitte
- Darshan Divakaran, North Carolina Department of Transportation

BREAK: 3:30pm to 3:40pm

Urban Air Mobility Townhall Discussion - 3:40pm to 4:25pm

Facilitators:

- Justin Guan, Arup
- Adam Cohen, University of California, Berkeley
- Matthew Beamer, Cambridge Systematics
- Ryan Dittoe, Sacramento County Department of Airports
- Seyedmirsajad Mokhtarimousavi, Florida International University

Advancements in aviation technology, such as urban air mobility, has the potential to dramatically transform and disrupt the transportation ecosystem. As part of this interactive townhall discussion, participants were divided into three groups with a facilitated discussion intended to probe the following key questions:

- How do you think UAM will evolve in the future?
- What use cases or scenarios do you think are likely in the near future with UAM aircraft and services?
- What is the role of public policy? What policies do you think are needed (or need to be changed) to enable UAM adoption?
- What is needed to support public acceptance, and prepare the public and private sectors for UAM?
- What further research is needed on UAM? How can TRB help support this research?

Rapporteurs Report Back and Final Wrap Up: 4:25pm to 4:30pm

Justin Guan, Arup
Adam Cohen, UC Berkeley

Workshop Slides

OPENING PRESENTATION: URBAN AIR MOBILITY: HISTORY, NUTS AND BOLTS, AND THE CURRENT STATE OF THE INDUSTRY - ADAM COHEN, UC BERKELEY

Urban Air Mobility:
History, Nuts and Bolts, and State of the Industry

Adam Cohen

Researcher, Innovative Mobility Research

Institute of Transportation Studies

University of California, Berkeley

apcohen@berkeley.edu

Twitter: AskAdamCohen

LinkedIn: AskAdamCohen

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Presentation Overview

- Introductions
- What is Urban Air Mobility?
  - Vision, Standards, and Definitions
- UAM Taxonomy
- History and Evolution of UAM
- The UAM Complete Trip
- Long Range Planning Considerations
  - Infrastructure and the Built Environment
  - Potential Equity and Societal Concerns
  - Commonly Asked Questions and the Role of Research

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What is Urban Air Mobility?

- Passenger mobility and goods delivery using a variety of manned and unmanned aircraft
- Potential to create additional transportation options and use cases, such as:
  - Commuter shuttles; air taxis; emergency and medical response; cargo delivery
- Numerous synergies with changes in transportation, such as electrification, automation, and cyber security
- More than 250 vertical take-off and land (VTOL) aircraft and electric rotorcraft are under development
- Market valued at approximately $5 billion USD in 2018
- Various sources estimate a global market potential of $7.9 to $15.2 billion USD by 2030
- Many studies estimate profitability for passenger mobility and goods delivery between 2028 and 2030
- Technology improvements forecast to reduce traveler cost and increase profitability

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NASA's Urban Air Mobility Vision

"Revolutionize mobility around metropolitan areas by enabling a safe, efficient, convenient, affordable, and accessible air transportation system for passengers and cargo"

NASA 2019

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Standards and Definitions

Legal definitions for urban air mobility are essential to:

- International harmonization
- Mainstream services
- Guide public policy
- Expand opportunities for public/private partnerships
- Foster industry-wide consumer education and outreach

Public agencies and industry associations should work together to develop clear, concise, and uniform definitions.

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SAE INTERNATIONAL JA3163 – Draft Definitions

Urban Air Mobility

A safe, efficient, accessible, quiet, and multi-use air transportation system for passenger mobility, cargo delivery, and emergency management within or traversing a metropolitan area.

Rural Air Mobility

A safe, efficient, accessible, quiet, and multi-use air transportation system for passenger mobility, cargo delivery, and emergency management within or traversing rural and exurban areas.

Abbreviated Notes:

1. May be abbreviated UAM/RAM, respectively
2. UAM/RAM can include both on-board/ground-piloted and autonomous operations.
3. UAM/RAM can include a combination of commercial and non-commercial operations such as: 1) business-to-consumer (B2C) service, 2) fractional and shared ownership models, 3) peer-to-peer (P2P) service, and 4) personally owned aircraft.

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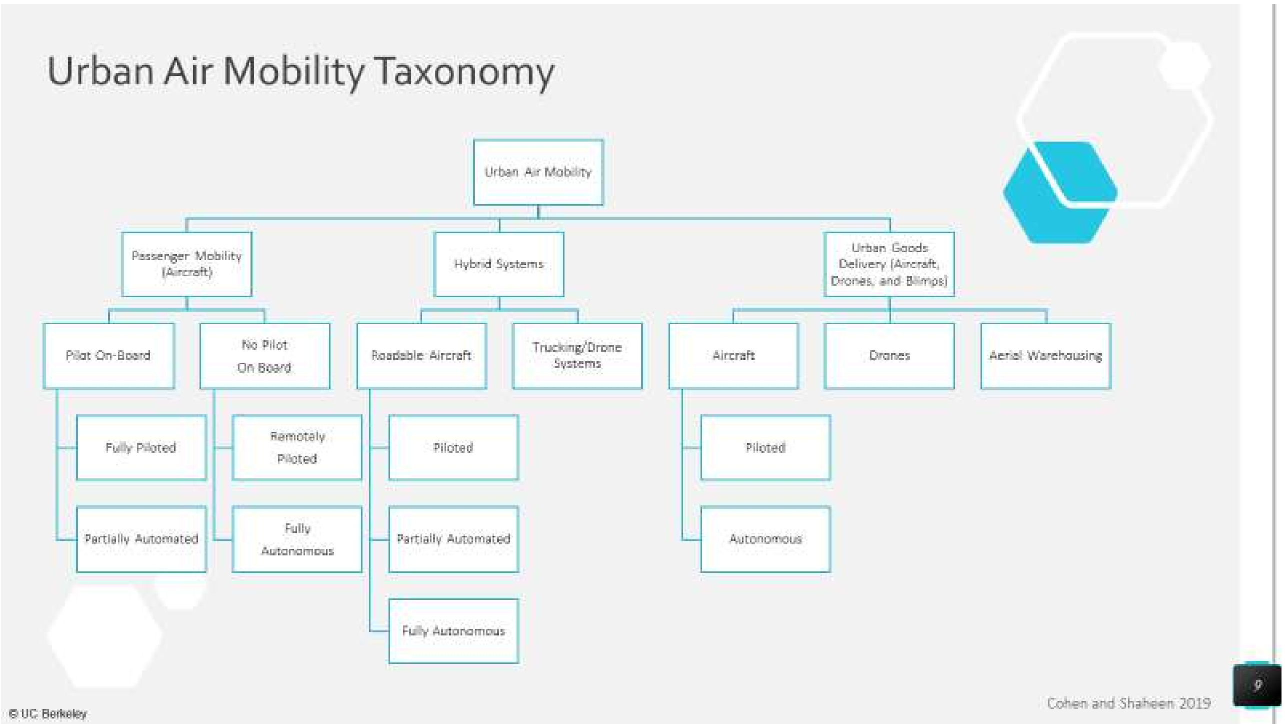
Urban Air Mobility Taxonomy
Urban Air Mobility
Passenger Mobility (Aircraft)
Hybrid Systems
Urban Goods Delivery (Aircraft, Drones, and Blimps)
Pilot On-Board
No Pilot On Board
Roadable Aircraft
Trucking/Drone Systems
Aircraft
Drones
Aerial Warehousing
Fully Piloted
Partially Automated
Remotely Piloted
Fully Autonomous
Piloted
Partially Automated
Fully Autonomous
Piloted
Autonomous
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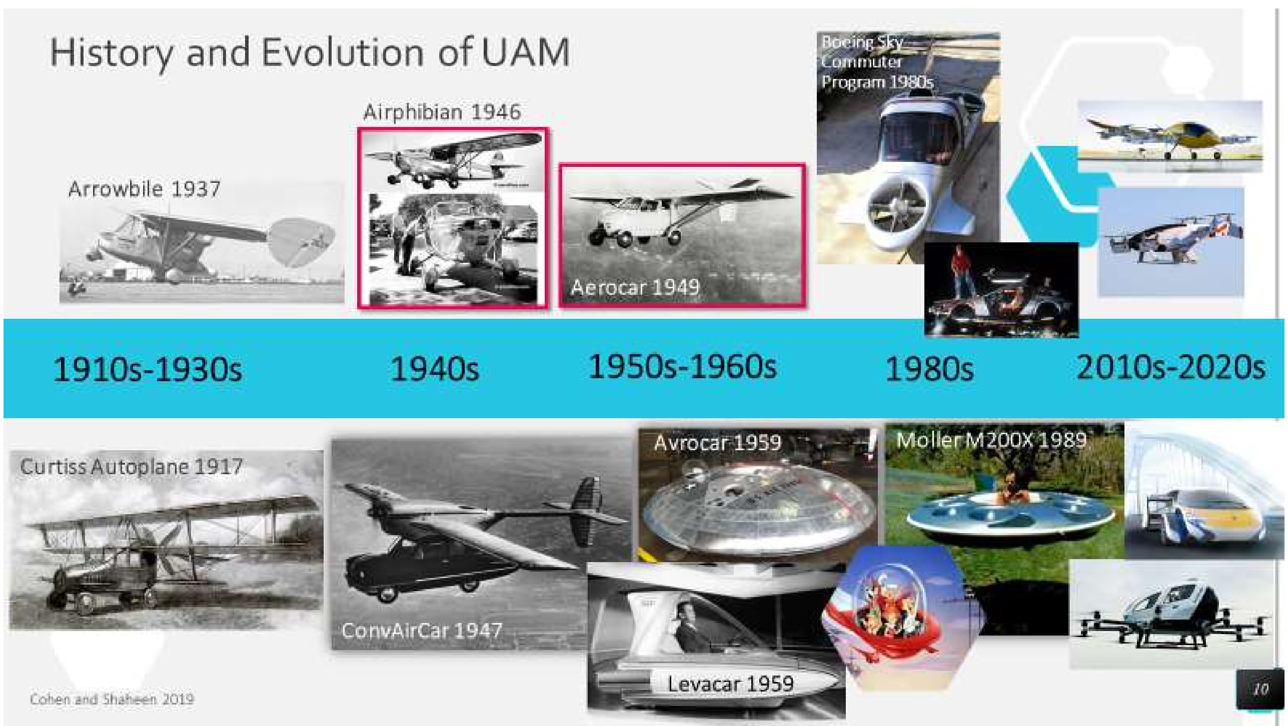
History and Evolution of UAM
Arrowbile 1937
Airphibian 1946
Aerocar 1949
Boeing Sky Commuter Program 1980s
1910s-1930s
1940s
1950s-1960s
1980s
2010s-2020s
Curtiss Autoplane 1917
ConvAirCar 1947
Avrocar 1959
Levacar 1959
Moller M200X 1989
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Evolution of Urban Air Mobility Passenger Services

1950s

- New York Airways offers passenger services between Manhattan and LaGuardia in the mid 1950s.

1960s and 70s

- Between 1965 and 1968 (resuming in 1977), PanAm offers first/last mile airport connections between JFK and Manhattan/Newark
- In May 1977, a rotor blade breaks off a helicopter on the roof of Manhattan's Pan Am Building, killing 5 people

1980s

- Trump Air provides scheduled helicopter service between LaGuardia and Wall Street, connecting to Trump Shuttle flights.

2010s

- A number of new services launch on-demand helicopter and fixed-wing services that arrange flights between passengers and charter operators
- Notable R&D into electrification and autonomous operations

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The UAM Complete Trip

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Long Range Planning Considerations

- How does UAM fit into the transportation ecosystem?
- Include UAM into long range policies and planning today
  - Incorporate UAM into multimodal capital projects
  - Develop zoning codes and design guidelines for vertiports
  - Plan to adapt other infrastructure for UAM
- Societal barriers and equity concerns
- UAM research

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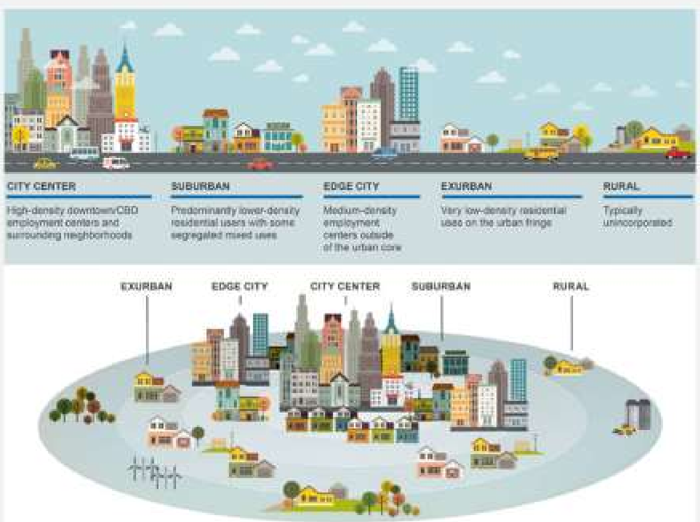
The Role of the Built Environment



- Context in the built environment matters
- One size does not fit all
- Solutions must be tailored to meet a diverse array of needs, use cases, and urban contexts
  - Small and rural communities
  - Auto-oriented mega regions
  - Transit-oriented mega regions

Shaheen and Cohen 2017; Shaheen et al. 2017

Urban Air Mobility Infrastructure

Vertipad:
A single landing pad and parking stand intended to accommodate one aircraft for parking, pick-up, and drop-off with minimal service infrastructure

Vertiport:
1-2 final approach and take off areas (FATOs) accompanied by 2-3 parking stands with charging facilities, and a small terminal

Vertihub:
A very large facility with 2 or more FATOs, multiple parking stands with charging facilities, and a larger terminal

(Cohen 2019)

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UAM Infrastructure Considerations

- What is the built environment we are trying to serve?
- Are we building new or repurposing existing infrastructure?
- What types of land uses/infrastructure need to be repurposed, renovated, or redeveloped to support UAM?
- What first and last mile connections are needed?
- How do we prioritize public transportation, pooled vehicles, and active transportation?
- How do we integrate UAM vertiports into nearby land uses?
- What are the adverse impacts and how do we mitigate them? (e.g., impacts on aesthetics, noise, walkability, urban density, etc.)

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Urban Air Mobility Infrastructure

Key considerations:

- Airspace access; aircraft parking, charging and battery swapping; facility security; and open access to accommodate a variety of aircraft types, operators, and users.
- **Overlay Zoning** is one regulatory tool that could be used to establish a special zoning district for UAM that can be placed over existing land uses to either limit building heights and/or preserve approach paths for either planned or potential UAM infrastructure under consideration.
- **Incentives** could be paired with overlay zoning to encourage particular types of UAM infrastructure – such as a vertiport located with public transportation and mobility hubs

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Understanding Equity Issues with UAM

USDOT STEPS Framework

Spatial barriers create physical gaps in the transportation network, such as the lack of service availability in a particular neighborhood, excessively long distances between destinations, and lack of public transit within walking distance.

Temporal barriers create gaps in the transportation network during particular travel times, such as the inability complete off-peak or late night trips due to lack of services

Economic barriers include financial challenges, such as high direct costs (e.g., fares, tolls), indirect costs (e.g., smartphone ownership), and structural barriers (e.g., banking access) that may preclude users from using MOD.

Physiological barriers include physical and cognitive limitations that make using standard transportation modes difficult or impossible for certain individuals (e.g., people with disabilities, older adults, etc.)

Social barriers include social, cultural, safety, and language challenges that may inhibit a potential traveler's comfort with using transportation modes and services (e.g., poorly targeted marketing, lack of multi-language information, neighborhood crime)

Shaheen et al. 2017

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Potential Concerns with Urban Air Mobility

- Equity, Accessibility, and Affordability
- Visual Pollution
- Noise Pollution
- Privacy and Increased Air Traffic Over Residential Areas
- Remotely Piloted and Autonomous Operations

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Community Air Mobility Initiative (CAMI)

CAMI Community Air Mobility Initiative

Who is CAMI?

- CAMI is a nonprofit organization dedicated to supporting the responsible integration of the third dimension of urban transportation at the state and local level.
- CAMI will educate and equip state and local decision makers, the public, and the media with the information they need to set policies and design infrastructure and systems that address transportation needs for their communities.
- CAMI will help the UAM industry better meet the needs of local stakeholders and maximize the value they bring to communities.
- CAMI recognizes that the successful implementation of UAM will hinge on acceptance by local communities, cities, states, and the general public.

CAMI Members:

- Support the widespread adoption of personal aviation as a solution to the transportation challenges faced by individuals and communities.
- Represent the entire ecosystem of stakeholders
- Prioritize safety, bring credibility to the organization, and have a demonstrated desire to be a good neighbor within their community.

Membership is accessible to a variety of organizations, and a broad swath of stakeholders.

For more information: www.communityairmobility.org
contact@communityairmobility.org

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Importance of UAM Research

- Need to develop data metrics, models, planning platforms, and methodologies to assess the economic and travel impacts of Urban Air Mobility
- Longitudinal tracking and forecasting of modal impacts
- Develop ability for public agencies to forecast the economic and travel behavior impacts of UAM/UAS pilot projects and guide public policy development
- Developing policies that balance data sharing with privacy (user, private companies, and public agencies)
- Key for providing seamless multi-modal integration

Shaheen and Cohen 2017

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Early Understanding of Potential Societal Barriers

- Generally, neutral to positive reactions to the UAM concept, with some skepticism
- Public perception of fully autonomous aircraft is one of the largest barriers
- Cost is a primary consideration
- Personal security was an important factor (e.g., confidence in the aircraft, security/safety from flying with potentially dangerous or unruly passengers)
- Some respondents expressed privacy concerns (e.g., people flying overhead, sight lines into homes/yards) and increased noise levels)

	Excited	Happy	Neutral	Confused	Concerned	Surprised	Skeptical	Amused
GEOGRAPHIC LOCATION	Survey Results							
Houston, N = 344	32%	24%	27%	8%	9%	11%	19%	3%
San Francisco Bay Area, N = 337	33%	25%	27%	8%	9%	11%	20%	3%
Los Angeles, N = 345	32%	24%	27%	8%	9%	11%	19%	3%
Washington, D.C., N = 341	32%	24%	27%	8%	9%	11%	20%	3%
New York City, N = 344	32%	24%	27%	8%	9%	11%	19%	3%
GENDER	Survey Results							
Female, N = 976	26%	22%	26%	10%	11%	11%	20%	4%
Male, N = 734	37%	23%	23%	6%	10%	8%	18%	4%
INCOME	Survey Results							
Less than $10,000, N = 78	14%	17%	40%	8%	3%	4%	10%	3%
$10,000 - $14,999, N = 53	19%	23%	30%	6%	6%	6%	6%	6%
$15,000 - $24,999, N = 101	25%	12%	36%	7%	3%	6%	7%	3%
$25,000 - $49,999, N = 212	28%	15%	27%	8%	5%	3%	11%	2%
$50,000 - $74,999, N = 210	28%	22%	25%	7%	4%	5%	8%	0%
$75,000 - $99,999, N = 192	30%	30%	14%	7%	5%	2%	9%	1%
$100,000 - $149,999, N = 182	36%	14%	25%	4%	6%	1%	12%	2%
$150,000 - $199,999, N = 101	27%	21%	20%	8%	6%	6%	9%	2%
$200,000 or more, N = 112	35%	12%	21%	7%	11%	4%	11%	0%
AGE	Survey Results							
18 - 24 years, N = 110	22%	25%	34%	5%	2%	4%	5%	2%
25 - 34 years, N = 271	32%	28%	19%	4%	4%	3%	8%	1%
35 - 44 years, N = 191	43%	16%	17%	6%	5%	2%	8%	3%
45 - 54 years, N = 132	30%	16%	21%	8%	9%	3%	9%	2%
55 - 64 years, N = 178	26%	15%	29%	9%	7%	4%	8%	1%
65 - 74 years, N = 169	14%	12%	33%	9%	6%	4%	18%	1%
75+ years, N = 42	10%	14%	31%	10%	7%	2%	24%	0%

Shaheen, Cohen, Farrar 2019

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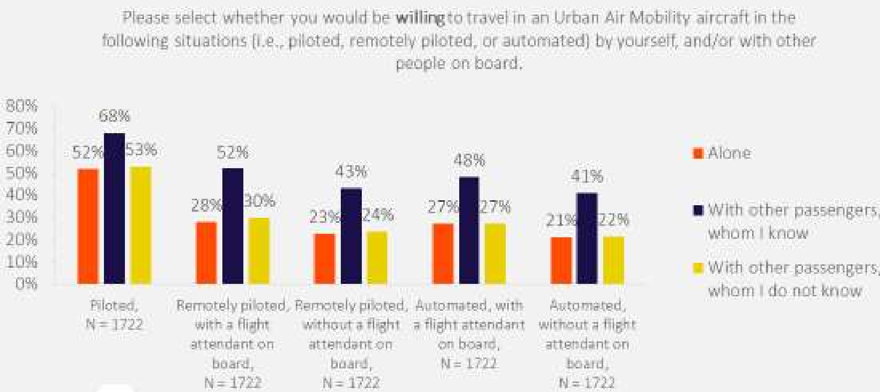
Early Understanding of Potential Societal Barriers



Study available at:
https://escholarship.org/uc/item/7p69d2bg

Shaheen, Cohen, Farrar 2019

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Understanding the Impacts of UAM/UAS

Shaheen and Cohen, 2017

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Starting Point: Evaluation Planning

- Develop project-specific goals/target impacts
- Develop and validate project-specific hypotheses
- Validate/augment suggested performance measures
- Identify details on data sources and data availability
  - Are there available data sources for baseline data? (i.e. data 'before' or 'without' the pilot to compare against?)
  - How will data be protected and stored?
  - Who are the target groups (of participants/stakeholders) for interviews and survey participation?
- Develop methods of evaluation

Shaheen and Cohen 2017

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Standardizing Industry Data Collection

- Industry-Wide Research
  - Optimum method: Before-and-after, creating long-term longitudinal data to track industry impacts and developments
  - Second-best design: Surveys that ask before using-and-after using changes in travel and vehicle ownership
  - Standardization (instrument/questions and timing) across all operators creates more powerful results for policy development, etc.
- Operator Partners with a Third-Party to Conduct Research
- Internal User Surveys
  - Consistent questions, administered at same time by each organization
  - Standardization (instrument/questions and timing) across all operators recommended
- Automated Data Collection
  - Incorporating telematics and "apps" to capture activity data

Shaheen and Cohen 2017

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Key Questions Asked by the Media

- Size of industry (members/users, aircraft/rotorcraft, revenue)
- Growth of industry over time
- Changes in industry segments and markets
- Industry snapshot of where the market is today and where it is going tomorrow
- Comparison of market size/growth among cities and regions
- Opportunities and obstacles

Shaheen and Cohen 2017

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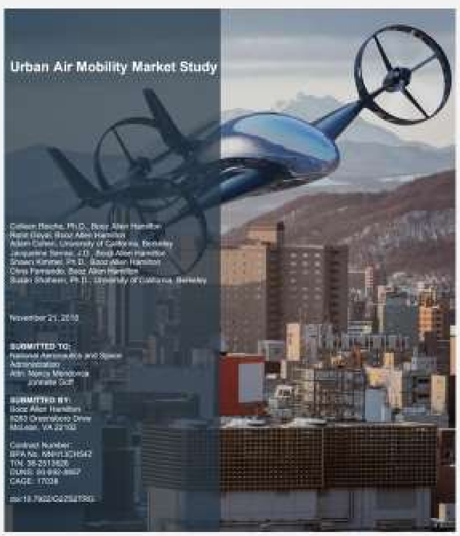
A Few Resources



https://escholarship.org/uc/item/0fz0x1s2

Link Coming Soon!

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Thank You
Special thanks to:
• Speakers and Moderators
• Transportation Research Board
• TRB Staff, Aviation Group and Committees
• Young Members Council – Aviation (YMC-A)
Adam Cohen, Innovative Mobility Research, UC Berkeley
apcohen@berkeley.edu
AskAdamCohen
AskAdamCohen
www.innovativemobility.org
© UC Berkeley


Potential Opportunities and Challenges of Urban Air Mobility (UAM)
Bill Goodwin
Joby Aviation
Christopher A. Hart
Former National Transportation Safety Board Chairman
Hart Solutions LLC
chris@hartsolutionsllc.com
Jim Herrera
UAM Program Manager / Industry Liaison
FAA
james.herrera@faa.gov
Tom Gunnarson
Lead of Regulatory Affairs
Wisk
tom.gunnarson@wisk.aero
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NASA Advanced Air Mobility (AAM) Research

Davis L. Hackenberg

Aeronautics Research Mission Directorate (ARMD) UAM Mission Manager & Advanced Air Mobility (AAM) Project Manager

NASA

davis.l.hackenberg@nasa.gov

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Community Acceptance & Public Perception

Mary Ellen Eagan

President, CEO, and Chairman of the Board of Directors

HMMH

meagan@hmmh.com

Daniel Friedenzohn

Associate Dean and Associate Professor of Aeronautical Science

Embry-Riddle Aeronautical University

friedend@erau.edu

Michael J. Doty

Head of Aeroacoustics Branch

NASA Langley Research Center

michael.j.doty@nasa.gov

Paul Wheeler

UAS/UAM Program Manager

Utah Department of Transportation

pwheeler@utah.gov

Rohit Goyal

Operations Planning Strategic Lead

Uber Elevate

rohitgoyal@uber.com

Chrishanth Fernando

Senior Associate

Booz Allen Hamilton

Fernando_chrishanth@bah.com

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Issues with Planning & Implementation
YuYu Zhang
Associate Professor - Department of Civil and Environmental Engineering
University of South Florida
yuzhang@usf.edu
Ghassan Khankarli
Assistant Director
City of Dallas Department of Transportation
ghassan.khankarli@dallascityhall.com
Fred Judson
UAS Director - Ohio UAS Center
Ohio Department of Transportation
fred.judson@drive.ohio.gov
Gregory J. Bowles
Head of Government Affairs
Joby Aviation
greg.bowles@jobyaviation.com
Ric Stephens
Senior Aviation Planner
WHPacific Inc., an NV5 company
rstephens@whpacific.com
33


Airspace Systems & Operations Challenges
Ella Atkins
Professor of Aerospace Engineering
University of Michigan
ematkins@umich.edu
Darshan Divakaran
UAS Program Engineer
North Carolina Department of Transportation
ddivakaran@ncdot.gov
Jim Gregory
Director of the Aerospace Research Center
Ohio State University
gregory.234@osu.edu
John M. Robbins
Unmanned Aircraft Systems Program Coordinator & Associate Professor
Embry-Riddle Aeronautical University
robbinsj@erau.edu
Byron Thurber
Associate
Arup
byron.thurber@arup.com
Christopher Metts
Specialist Executive, Federal – Transportation / Aviation
Deloitte
cmetts@deloitte.com
34

Roundtable Discussion

Justin Guan, AICP
Aviation Planner
Arup
justin.guan@arup.com

Adam Cohen
Researcher
Innovative Mobility Research, University of California, Berkeley
apcohen@berkeley.edu

Matthew Beamer
Transportation Analyst
Cambridge Systematics, Inc.
MBeamer@camsys.com

Ryan Dittoe, C.M.
Airport Planner
Sacramento County Department of Airports
DittoeR@saccounty.net

Sajad Mokhtarimousavi
Graduate Research Assistant, Lehman Center for Transportation Research
Florida International University
smokh005@fiu.edu

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Roundtable Discussion

1. How do you think UAM will evolve in the future?
2. What use cases or scenarios do you think are likely in the near future with UAM aircraft and services?
3. What is the role of public policy? What policies do you think are needed (or need to be changed) to enable UAM adoption?
4. What is needed to support public acceptance, and prepare the public and private sectors for UAM?
5. What further research is needed on UAM? How can TRB help support this research?

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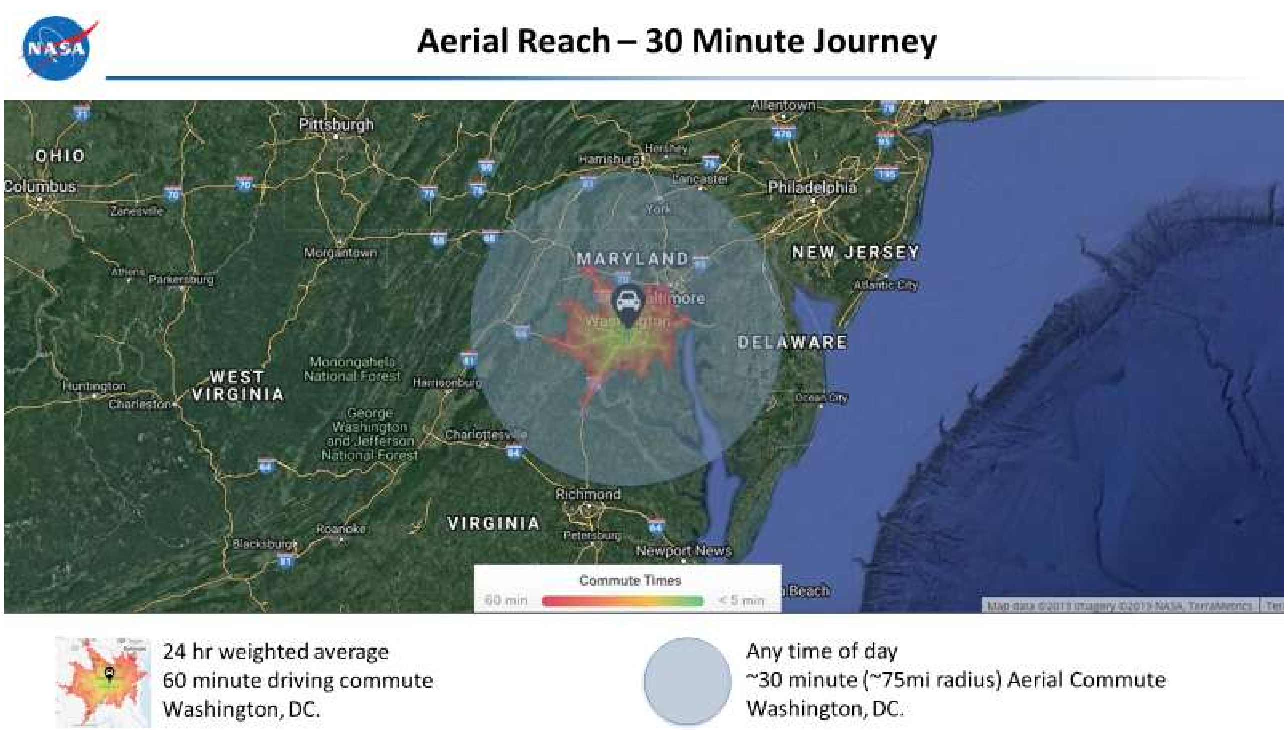
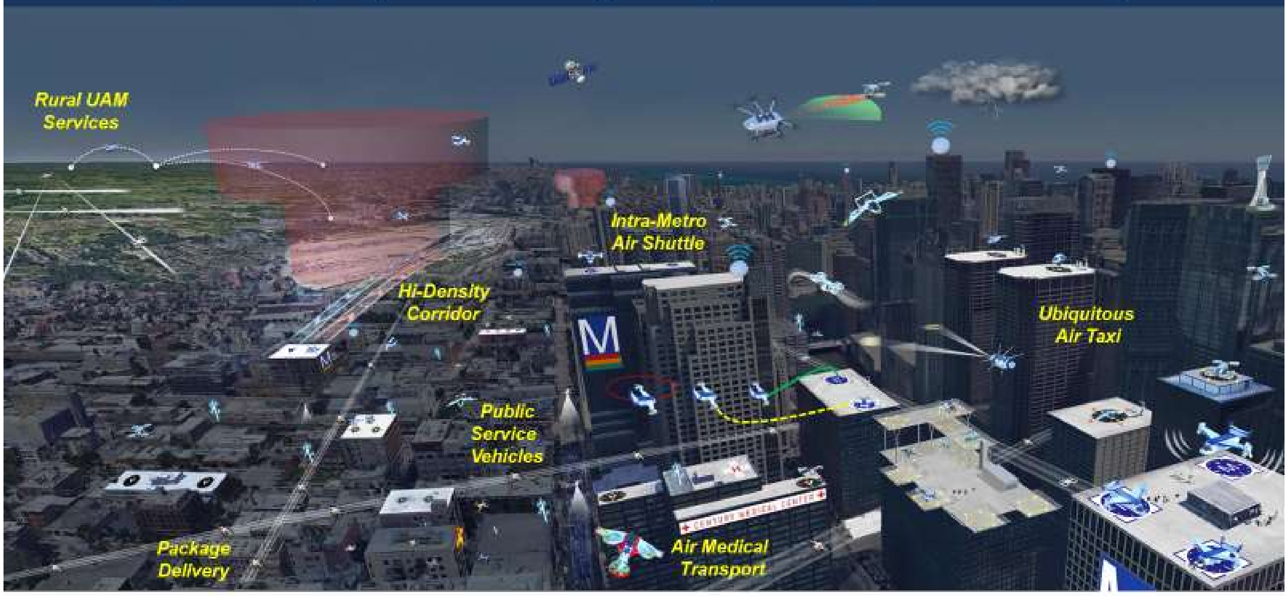
SPOTLIGHT SESSION: NASA ADVANCED AIR MOBILITY (AAM) RESEARCH - DAVIS HACKENBERG, NASA



ARMD UAM Vision

Develop a "Book of Requirements" to define a safe and certifiable scaled UAM system



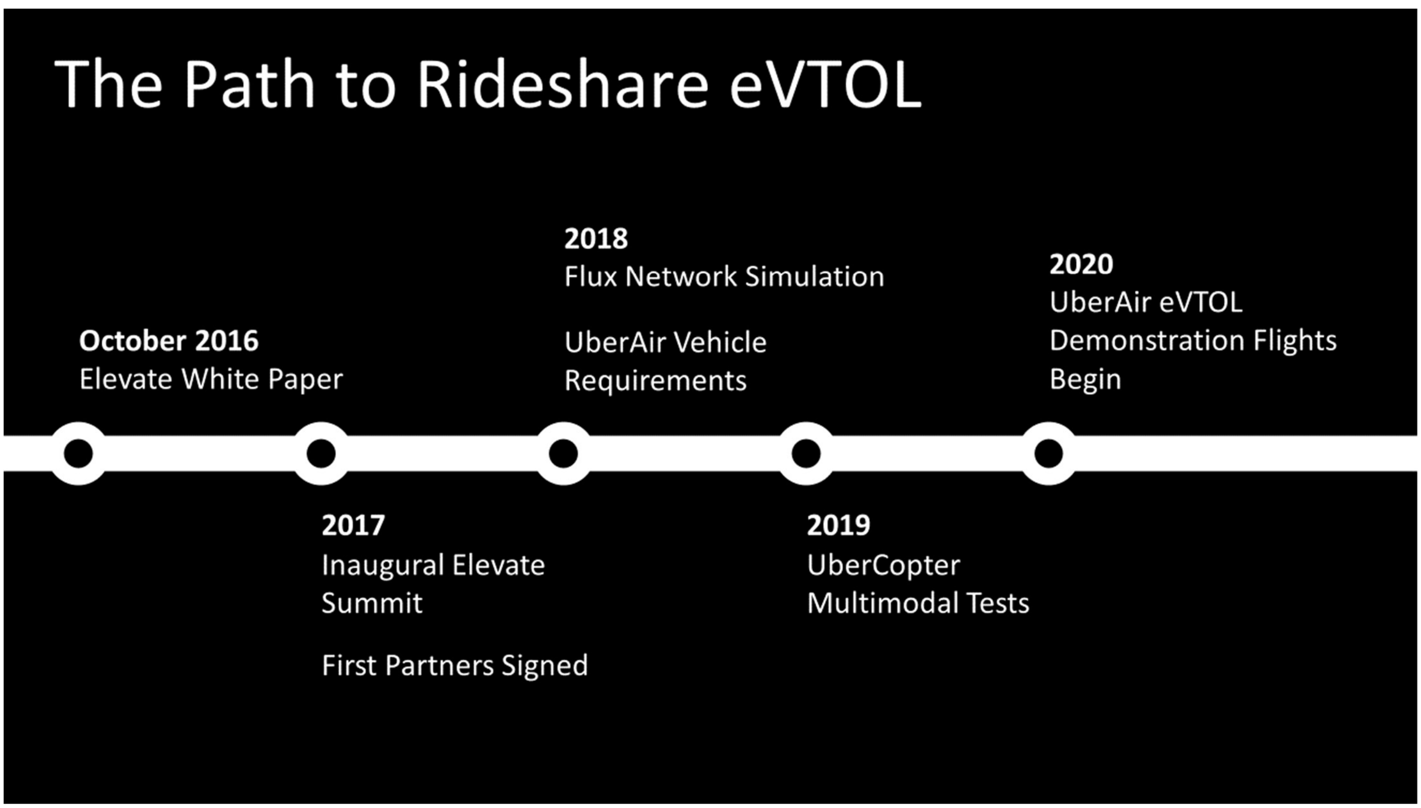
The First UAM Grand Challenge

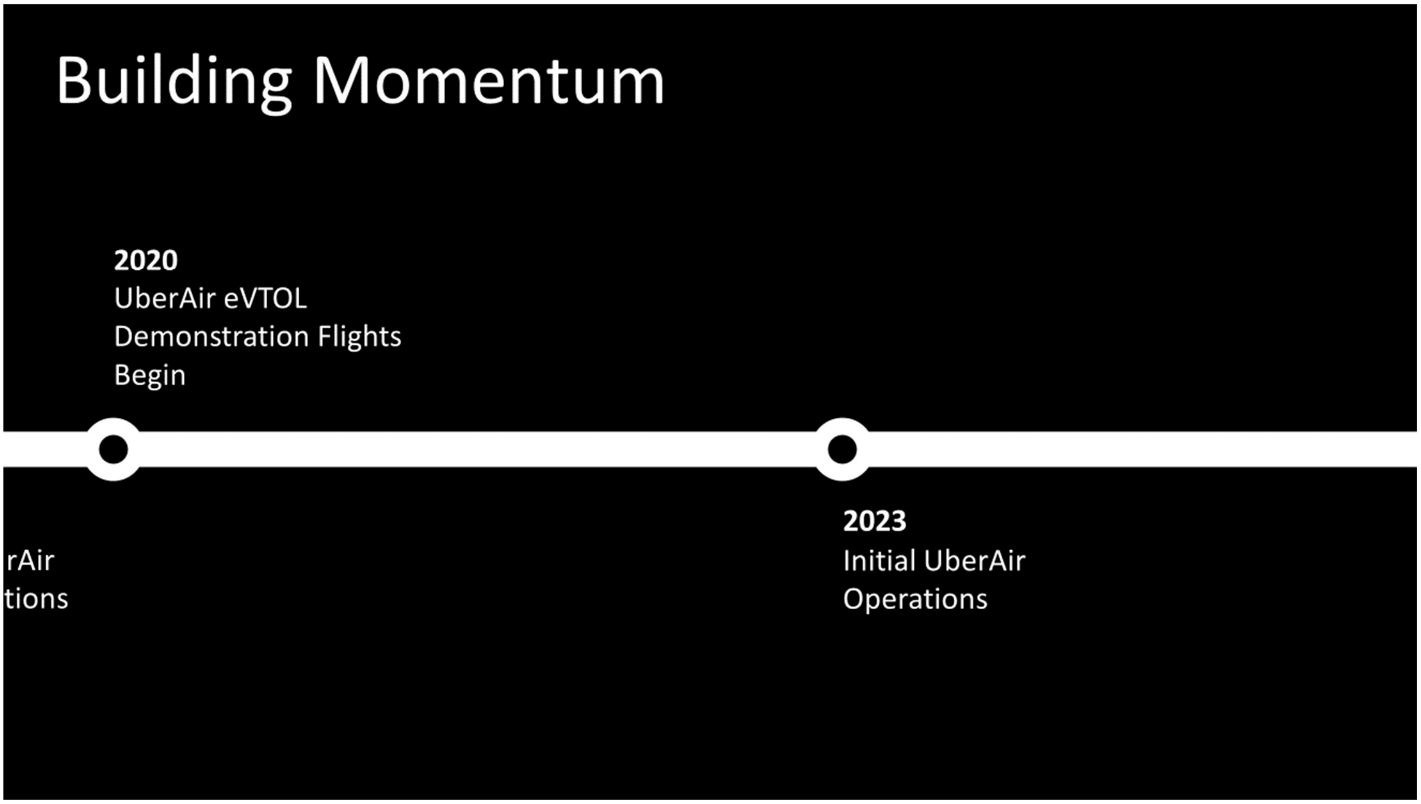
Goal — **Improve UAM safety and accelerate scalability through integrated demonstrations of candidate operational concepts and scenarios**

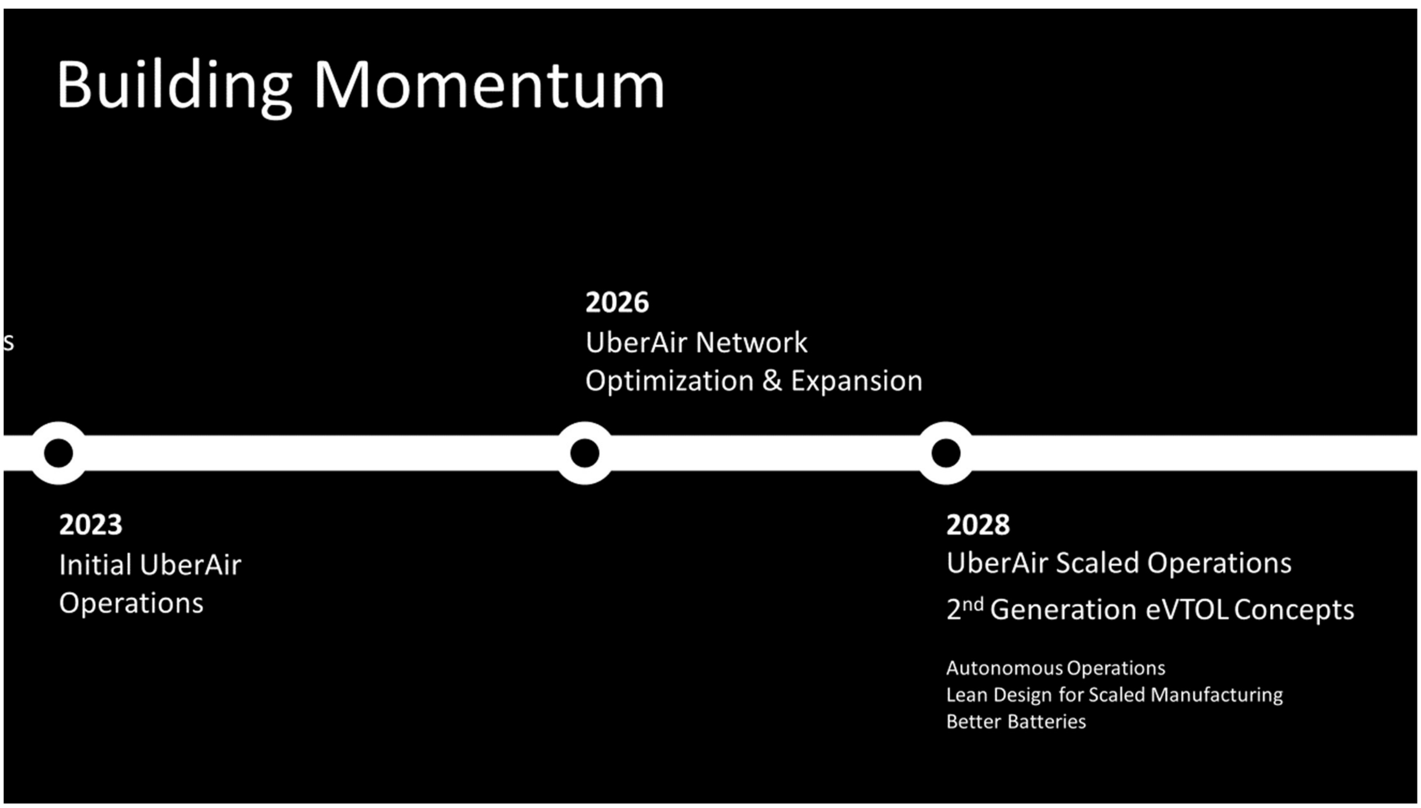
Objectives

1. Accelerate Certification and Approval
2. Develop Flight Procedure Guidelines
3. Evaluate the CNS Trade-Space
4. Demonstrate an Airspace Operations Management (AOM) Architecture
5. Characterize Community Concerns

SESSION 2: COMMUNITY ACCEPTANCE & PUBLIC PERCEPTION – ROHIT GOYAL, UBER




Building Momentum
2020
UberAir eVTOL
Demonstration Flights
Begin
rAir
tions
2023
Initial UberAir
Operations


Building Momentum
s
2026
UberAir Network
Optimization & Expansion
2023
Initial UberAir
Operations
2028
UberAir Scaled Operations
2nd Generation eVTOL Concepts
Autonomous Operations
Lean Design for Scaled Manufacturing
Better Batteries

Tech Readiness

Battery cycle testing validates Elevate mission near-term

Productivity

High speed, utilization, and pax load factors are critical

Noise

UAM market requires large noise reduction from heli's

Cost

Maintenance and energy costs reduce operating costs by 35%

Safety

Digital DEP control allows complexity while avoiding criticality

Certification

Standard practices present an opportunity for high volume of eVTOL operations

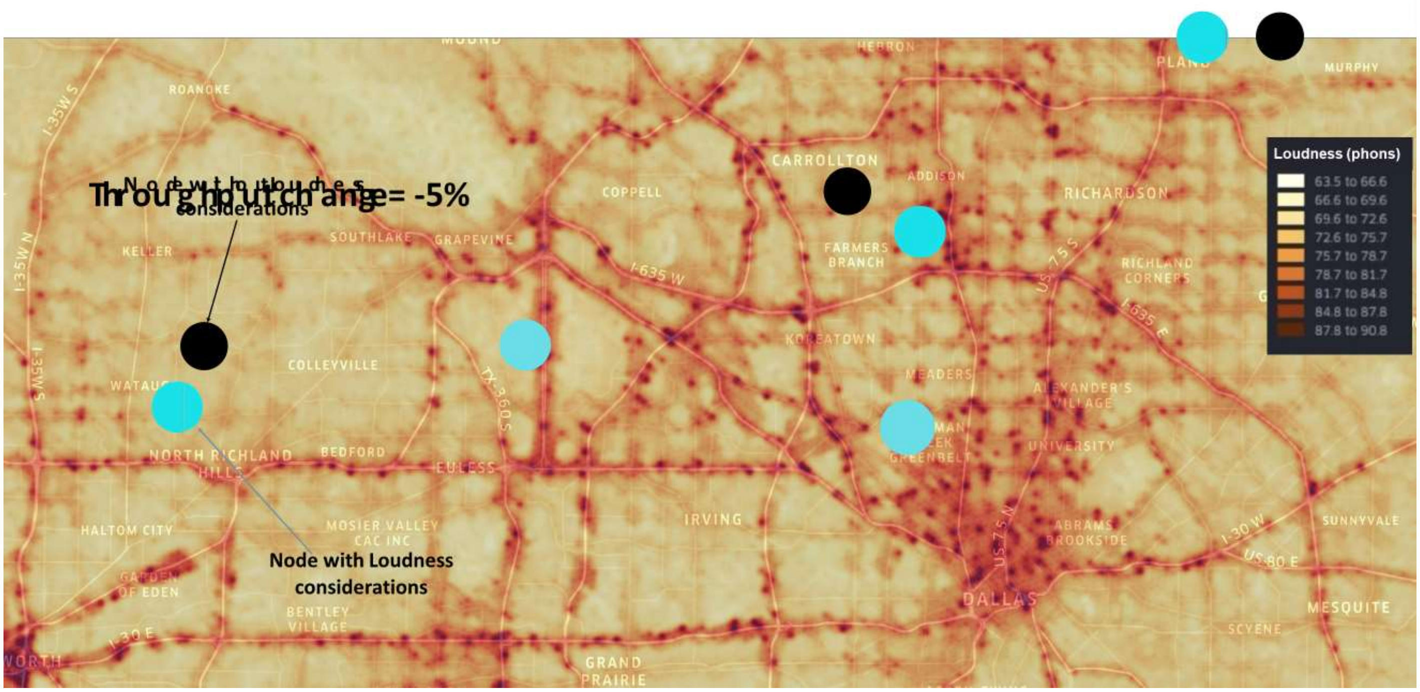
Project Symphony

Loudness

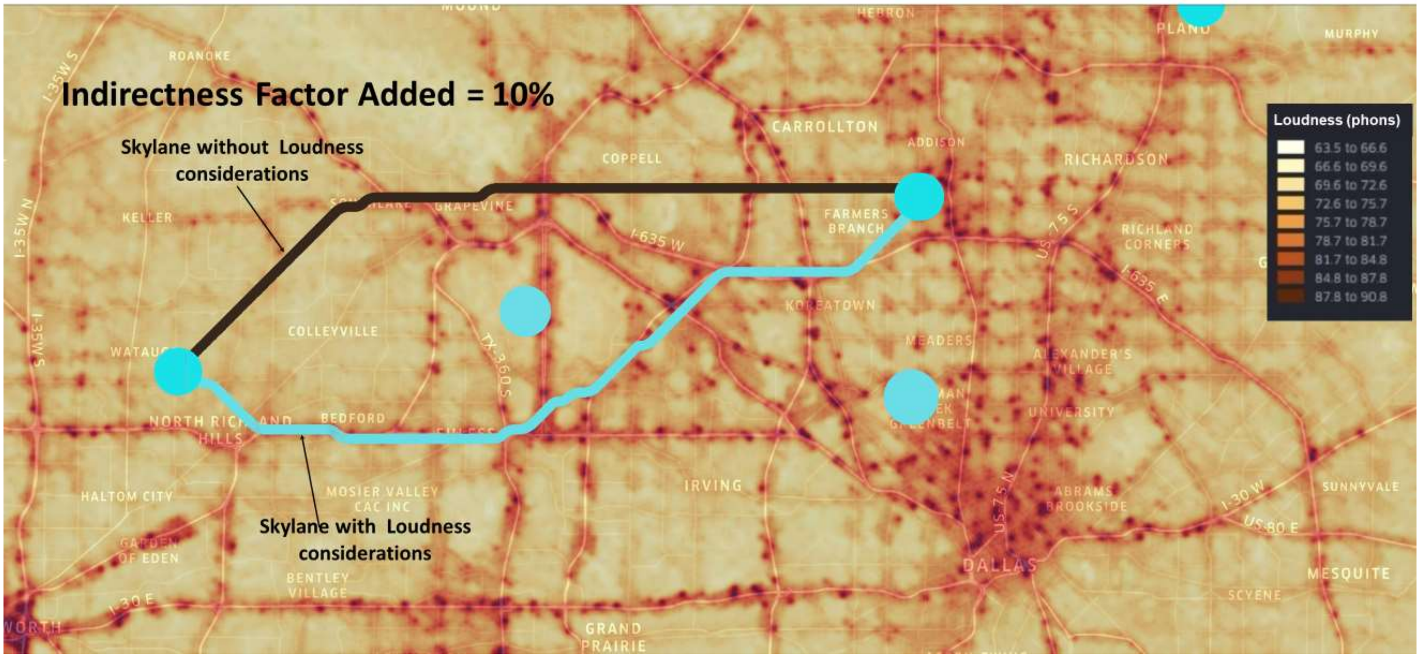
Predict ambient loudness at any location and time

Model the incremental loudness of Uber Air operations

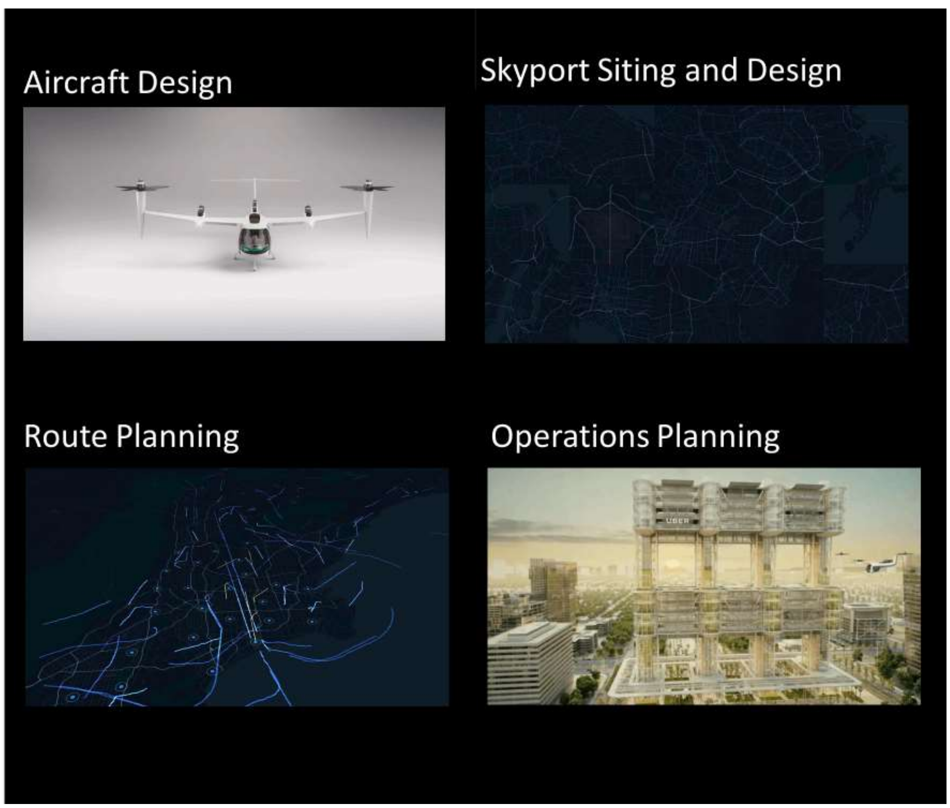
Node Optimization based on Loudness



Skylane network optimization using Loudness



Feasibility path for societal acceptance of Uber Air operations



Uber

Opportunities for Collaboration

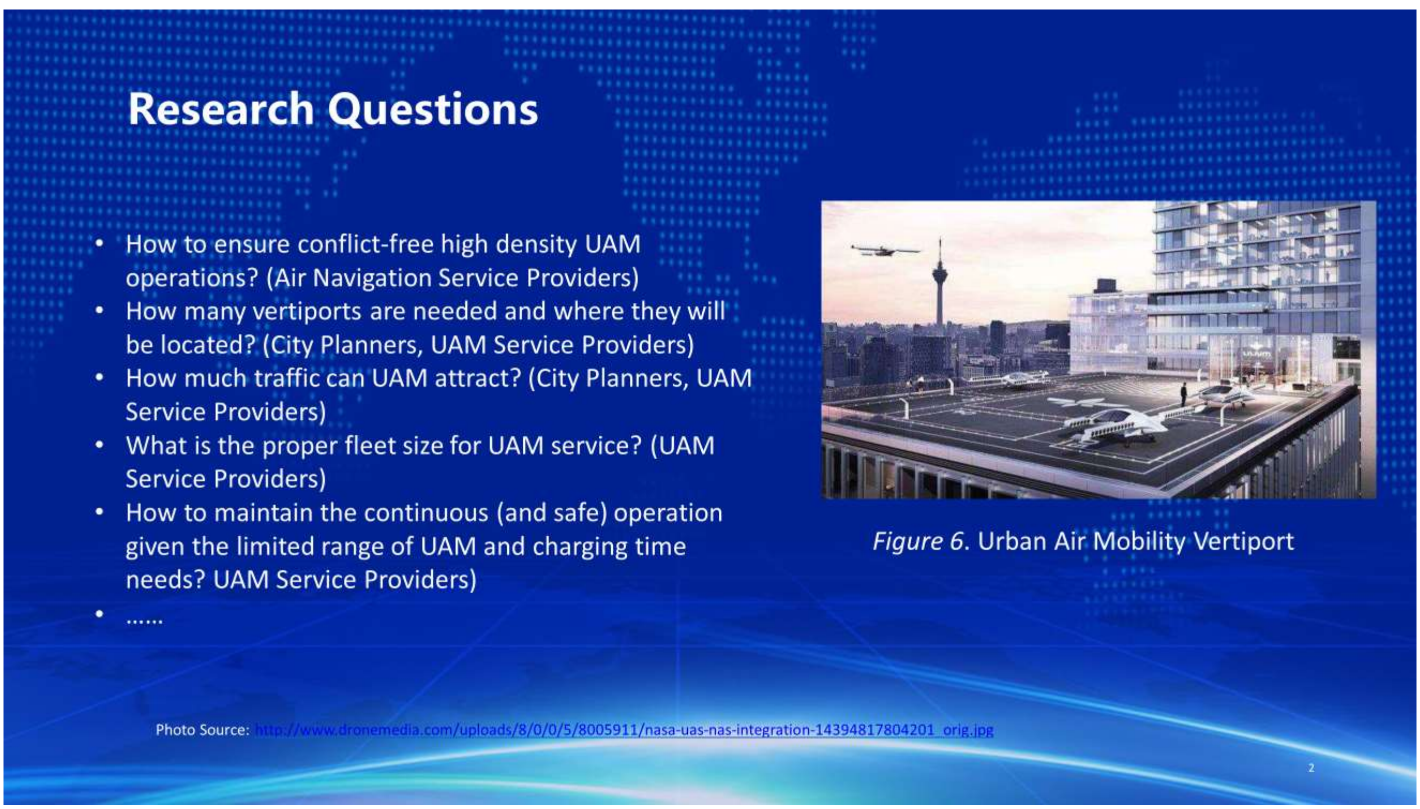
Tools & Technologies
Broadband and interaction noise modeling

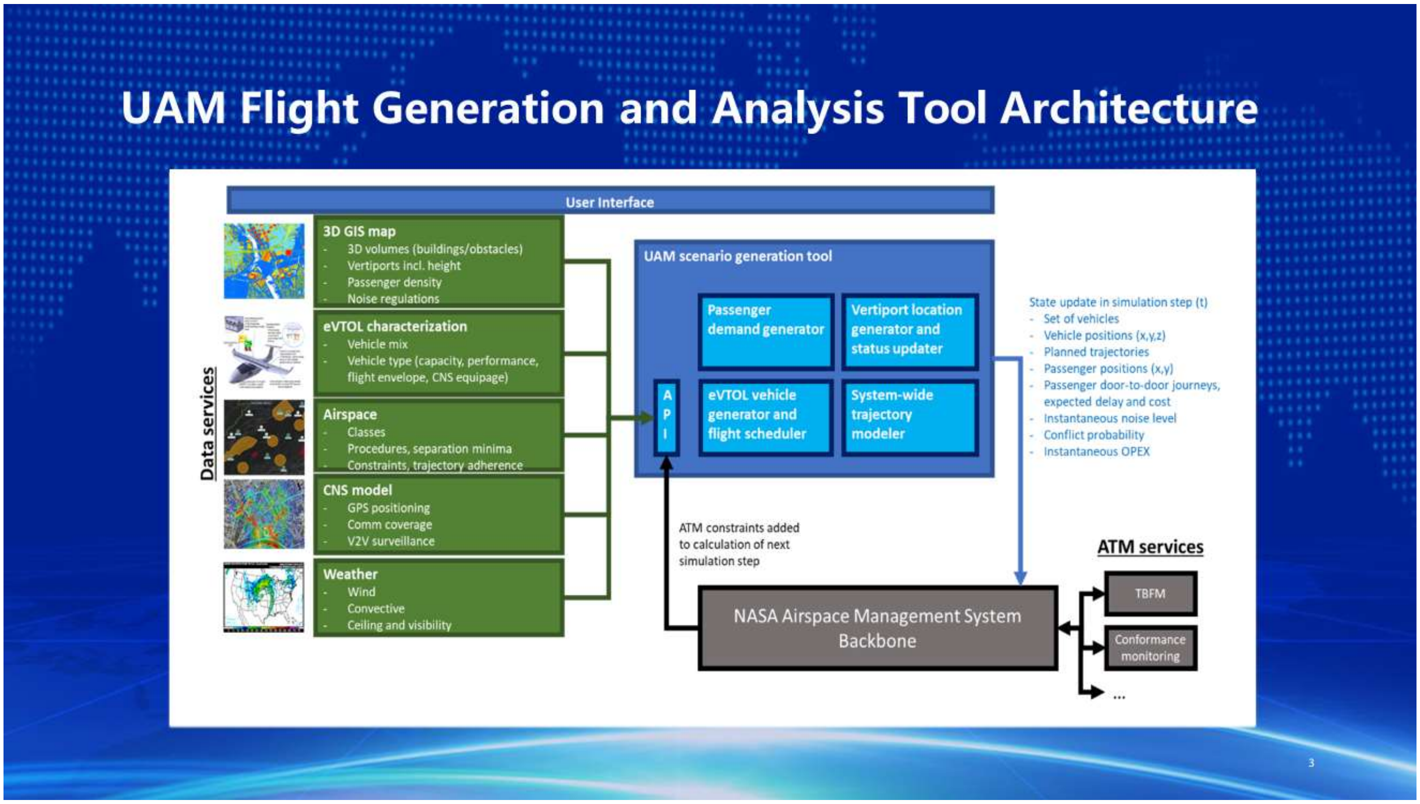
Ground and Flight Testing
Increasing availability of recordings and validation datasets

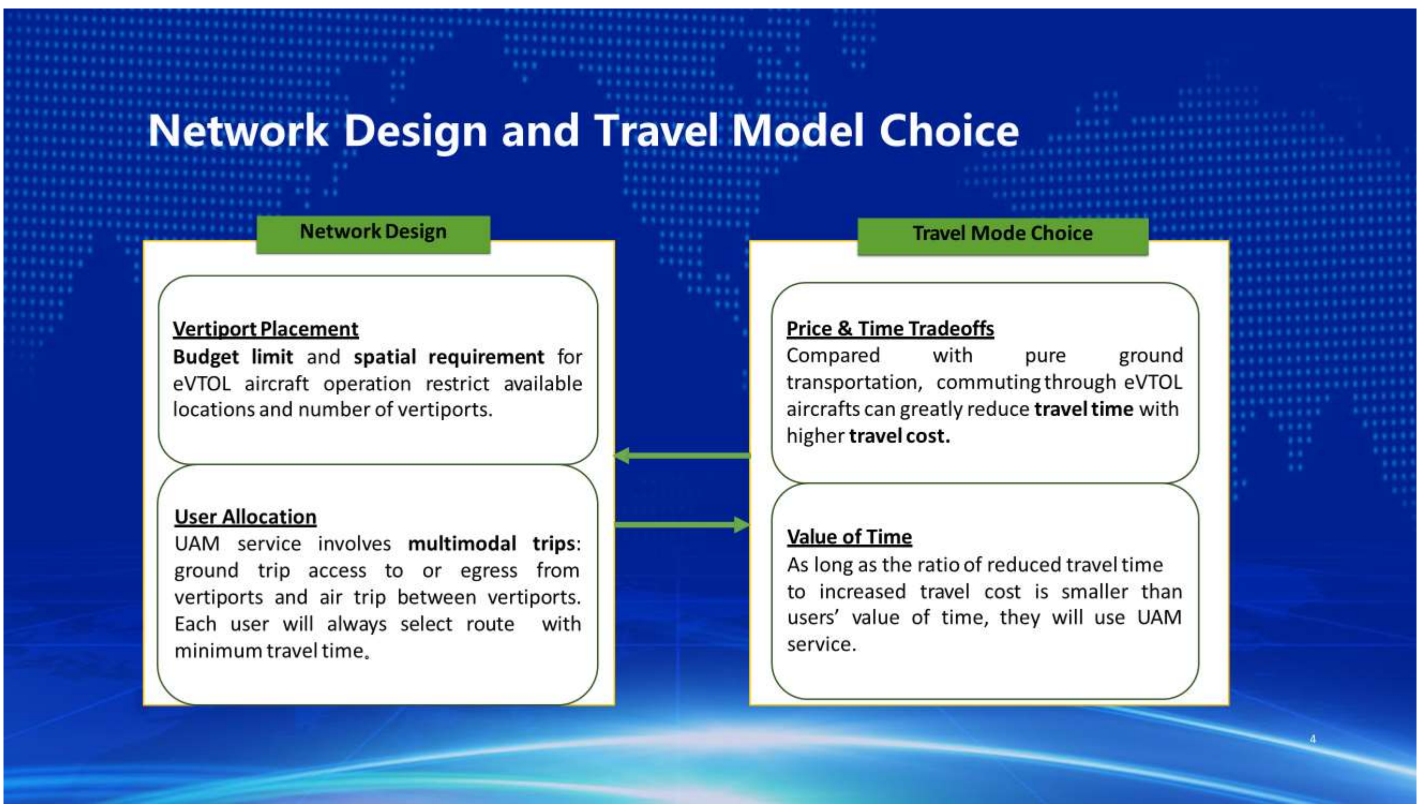
Metrics
Consensus on noise metric focused on community impact

Regulation & Policy
Joint effort with Vertical Flight Society and GAMA to work on re-issuance/re-write of AC 150/5020-2 (1983)

SESSION 3: ISSUES AROUND PLANNING AND IMPLEMENTATION – YUYU ZHANG, UNIVERSITY OF SOUTH FLORIDA




UAM Flight Generation and Analysis Tool Architecture
User Interface
Data services
3D GIS map
- 3D volumes (buildings/obstacles)
- Vertiports incl. height
- Passenger density
- Noise regulations
eVTOL characterization
- Vehicle mix
- Vehicle type (capacity, performance, flight envelope, CNS equipage)
Airspace
- Classes
- Procedures, separation minima
- Constraints, trajectory adherence
CNS model
- GPS positioning
- Comm coverage
- V2V surveillance
Weather
- Wind
- Convective
- Ceiling and visibility
UAM scenario generation tool
API
Passenger demand generator
Vertiport location generator and status updater
eVTOL vehicle generator and flight scheduler
System-wide trajectory modeler
State update in simulation step (t)
- Set of vehicles
- Vehicle positions (x,y,z)
- Planned trajectories
- Passenger positions (x,y)
- Passenger door-to-door journeys, expected delay and cost
- Instantaneous noise level
- Conflict probability
- Instantaneous OPEX
ATM constraints added to calculation of next simulation step
NASA Airspace Management System Backbone
ATM services
TBFM
Conformance monitoring
...
3


Network Design and Travel Model Choice
Network Design
Vertiport Placement
Budget limit and spatial requirement for eVTOL aircraft operation restrict available locations and number of vertiports.
User Allocation
UAM service involves multimodal trips: ground trip access to or egress from vertiports and air trip between vertiports. Each user will always select route with minimum travel time。
Travel Mode Choice
Price & Time Tradeoffs
Compared with pure ground transportation, commuting through eVTOL aircrafts can greatly reduce travel time with higher travel cost.
Value of Time
As long as the ratio of reduced travel time to increased travel cost is smaller than users' value of time, they will use UAM service.
4

Single Allocation Hub-and-Spoke Network

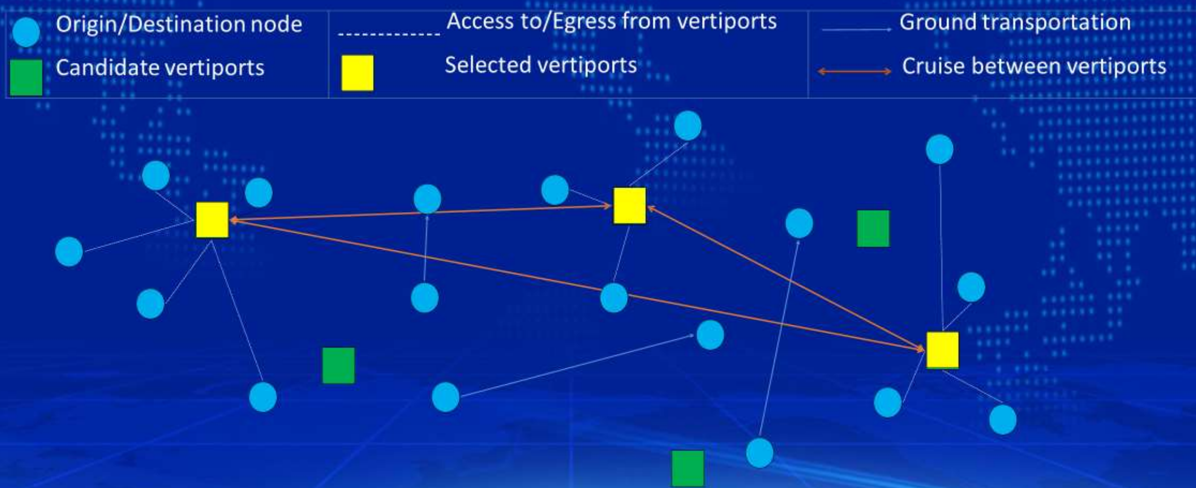


Figure 7. Single allocation hub-and-spoke network illustration

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Case Study-Data Source Description

- The study area includes **Hillsborough , Pinellas, Pasco, Hernando, and Citrus Counties of Florida**. **Port Manatee area** of Manatee county and the **I-75/I275 loop** and **interchange** are included as well.
- The data source for the numeric study is the travel demand data simulated from Tampa Bay Regional Planning Model (TBRPM), which is the model FDOT, District 7 and MPO uses in forecasting future travel demand。

Figure 8. Tampa Bay Regional Planning Model Study Area

6

Case Study-Results Analysis

Table 3. Number of trips through each selected vertiport

Vertiport Index	2	3	4	7	12	13	14	15	16	18
Demand	**969**	**368**	**269**	**643**	**495**	**202**	**369**	**509**	**827**	**384**
Vertiport Index	19	24	25	28	30	31	32	34	35	42
Demand	**482**	**560**	**450**	**461**	**515**	**779**	**314**	**291**	**291**	**730**
Vertiport Index	43	44	48	53	55	56	57	74	78	79
Demand	**410**	**1016**	**693**	**620**	**317**	**308**	**206**	**257**	**118**	**243**

7,019 *trips of 99,207* = **7%**

- Vertiport demand unevenly-distributed
- Northern region under-served

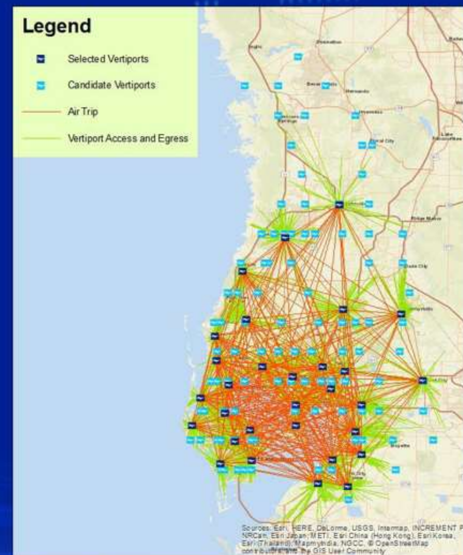

Figure 9. Identified optimal vertiport locations and user allocation

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Travel Distance of UAM Trips and Travel Time Saving

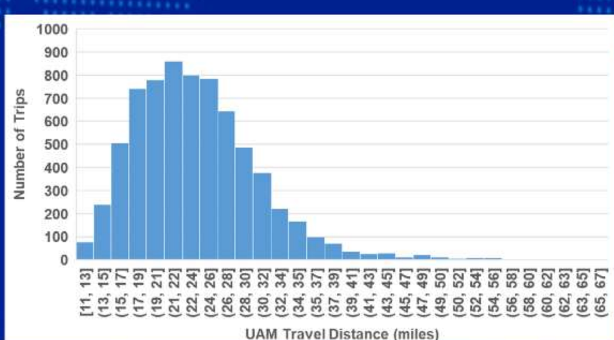

Figure 10. Multimodal UAM travel distance

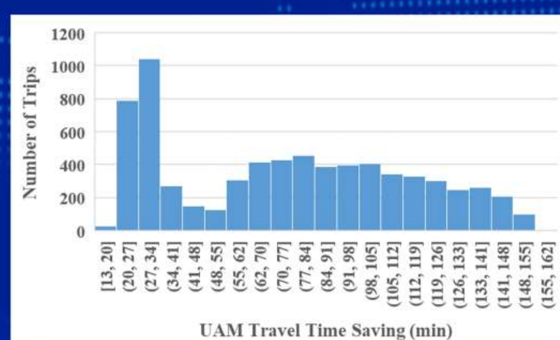

Figure 11. Multimodal UAM travel time saving distribution compared to ground transportation

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How Many Vertiports for Tampa Bay Area?

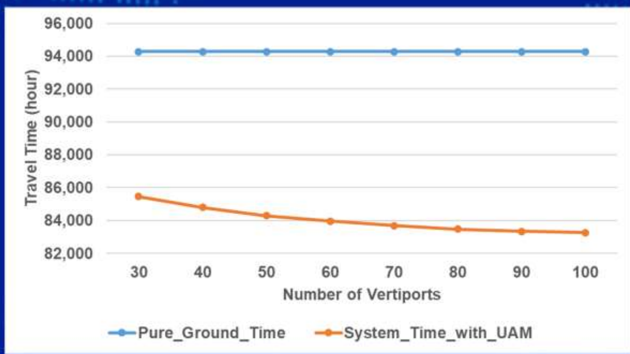

Figure 12. System travel time variation

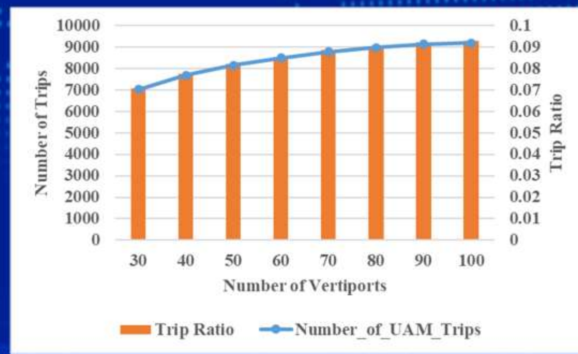

Figure 13. UAM adoption variation

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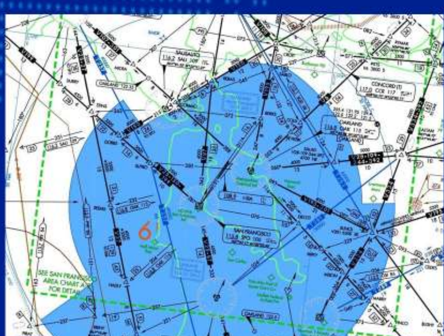
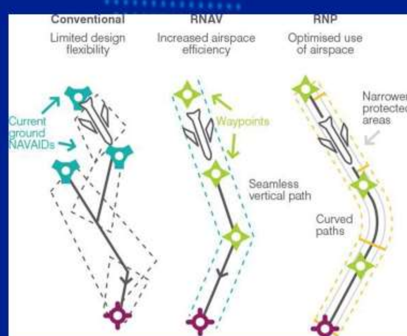
Structured or Unstructured Airspace System?



This instrument flight rules chart shows low altitude airways in the Oakland Area Control Center (near San Francisco, California).



Transition from conventional navigation to RNP https://www.casa.gov.au/book-page/chapter-6-performance-based-navigation

Is this how the future air traffic look like?

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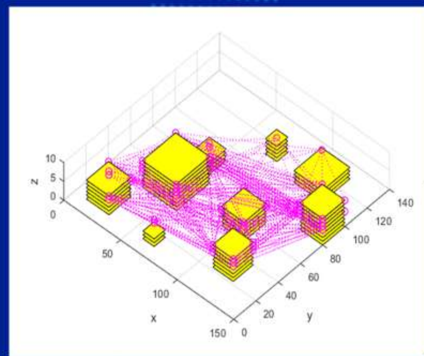
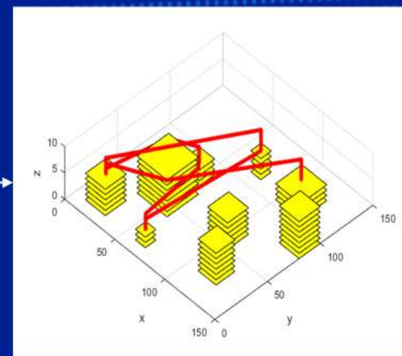
Adaptive Airspace System for Low Altitude High Density Operations

- Layered airspace with no other structures
- Trajectory based operations
- Time-based conflict detection and resolution
  - Assign different flight layer
  - Displace departure time
  - Control speed



Visibility Graphs to construct possible flight trajectories



Sample of 3D shorted paths in terms of energy consumption

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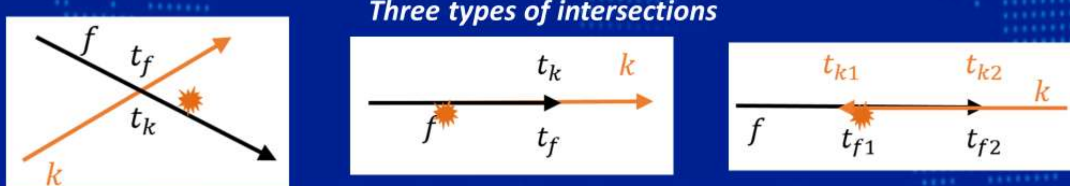
Time-Based Conflict Detection and Resolution

Compare the time interval of two aircraft passing the intersection point with minimum temporal separation

Three types of intersections



(1) Pure intersection

(2) Collinear with same direction

(3) Collinear with opposite direction

(a) $|t_f - t_k| \geq \delta$

$(b)\ t_{f1} \geq t_{k1} + \delta\ \ or\ \ t_{f2} + \delta \leq t_{k2}$

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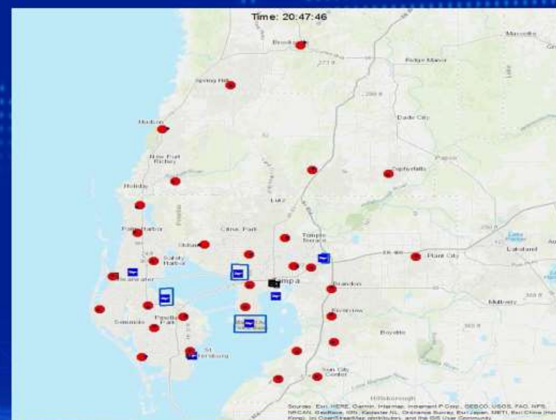
Case Study - Tampa Bay Area Animation of UAM Operations



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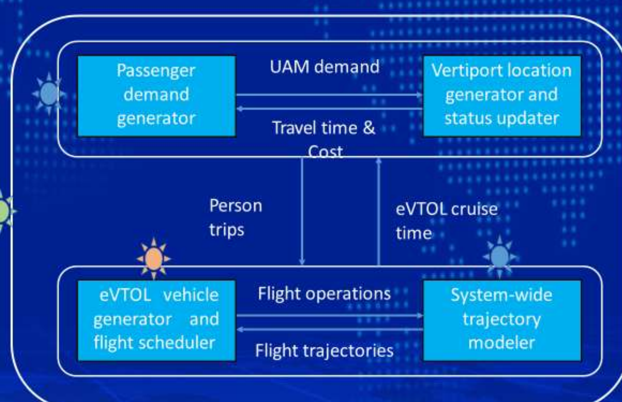
On-going Effort

- Extending vertiport location and passenger allocation by considering uncertainties from weather and ground transportation conditions
- Modeling arrival sequencing and departure assignment considering charging needs
- Developing procedures of UAM operations on and near commercial airports



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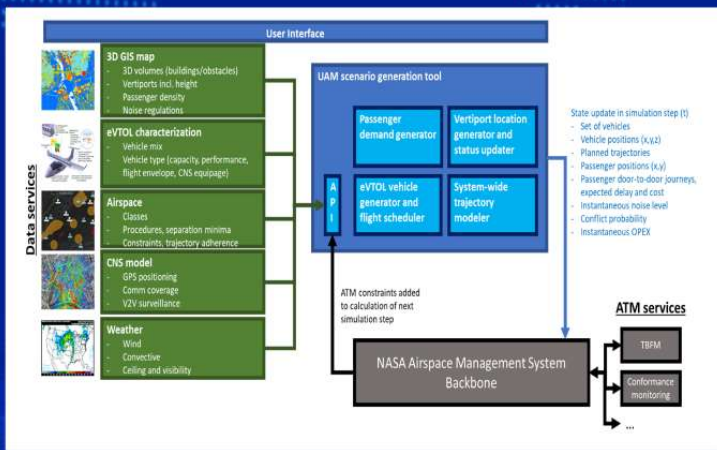
Anticipated Final Product



Serve the needs of :
- Policy maker
- Air navigation service provider
- City planner
- UAM service provider

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THANK YOU

yuzhang@usf.edu