Headway

URBAN AIR MOBILITY POLICY RECOMMENDATIONS FOR THE NEXT 5 YEARS

URBAN AIR MOBILITY

WELCOME

Throughout history, transportation has been a powerful catalyst for cultural, political and technological change. In the past century alone, we've seen countless examples of radical social progress accompanied by quantum leaps in ground and air transportation technologies, and that joint evolution of society and technology continues today. There is little doubt that the century ahead will introduce revolutionary new modes of transport, and Urban Air Mobility (UAM) ranks among the most promising. With this paper, we hope to facilitate the advent of UAM by providing viable policy recommendations for the next five years across five key areas of focus, with the aim of guiding industry stakeholders in bringing the vision of UAM to life.

Urbanization has pushed ground mobility to its limits, causing congestion, lost productivity and negative environmental impacts. We envision UAM as part of the mobility solution. UAM has the potential to merge air and ground transportation together as never before, using urban airspace to create a safe and seamless multimodal system. While UAM broadly covers cargo delivery use cases, this document will focus on passenger transportation, which will demand the highest safety and security standards, and particularly complex collaborations between disparate ecosystem stakeholders.

As we strive to make UAM a reality for cities and communities around the world, it is important to contemplate and solve for the barriers that are most likely to stand in our way. That's why, in 2019, we conducted an extensive and rigorous UAM literature review of more than 40 industry reports and position papers. In this review, we found numerous industry white papers, market studies, vehicle designs and some practical demonstrations that modeled UAM.

These examples inspire hope for UAM implementation and that it can become an answer to many of the ongoing transportation issues plaguing urban environments. What the literature lacks, however, is a comprehensive effort that tackles the hardest part of UAM implementation: policy development.

As we've seen from recent attempts at Unmanned Aircraft Systems (UAS) integration in the airspace, and e-scooter initiatives on our city streets, the failure to build sound policy and regulatory foundations for a budding new technology can quickly nullify much of its potential. Policy and flexible regulatory frameworks define roles and responsibilities for government, industry and the public to ensure safety, security and public confidence – all vital elements in any effort to help a new technology live up to its commercial promise.

To address this vacuum, we have developed UAM policy recommendations with the aim of helping industry stakeholders work alongside the communities that will benefit most from this emerging technology. When innovations are brought to market with progressive policies and thoughtful community engagement, it increases the likelihood of adoption by addressing significant issues before they occur.

Our position on UAM implementation is that this effort requires close collaboration between all UAM stakeholders to ensure a credible, sustainable and actionable policy framework. We intend for this paper to serve as a credible, viable public resource for the entire UAM ecosystem, including community organizations, state and local authorities, public agencies, original equipment manufacturers (OEMs) and suppliers, standards developing organizations (SDOs), academia and the investor community.

UAM policy should be as resilient and sustainable as the mode of transportation it is designed to support. With the world's population projected to hit 9 billion by 2050, based on our research, we believe it is time to invest in new transportation systems to meet the mobility demands of the world's citizens. However, we must first work to establish the policies and standards that can enable those systems for the long-term. We are hopeful that, with the vision and support provided by an expert and diverse group of partners, UAM will become a key element of the future of transportation.

EXECUTIVE SUMMARY

By 2030, it is estimated that almost 60% of the world's population will live in urban areas, amplifying the need for innovative and sustainable modes of transportation within and between cities. Urban air mobility (UAM) represents an unprecedented convergence of air and ground transportation systems, utilizing urban airspace and innovative infrastructure. In this paper, we present policy recommendations for actions to be taken over the next five years by state and local authorities, industry, policymakers, Standard Development Organizations (SDOs), academics, and other interested parties to move UAM forward in five essential policy areas: community integration, traffic management, infrastructure, security, and vehicle development.

When considered as a component of broader urban mobility master planning, UAM offers a breadth of valuable use cases across various aircraft types and settings. For this paper we will focus specifically on policy recommendations for urban passenger transportation and vertical take-off and landing (VTOL) vehicles. We view passenger transportation as the use case that will require the highest safety standards, infrastructure integration and public acceptance efforts. Based on lessons learned from other promising modal technology, it seems prudent to start addressing these considerations now in order for the stakeholder ecosystem to prepare for acceptance and integration of the technology once it is certified for civilian use.

The objective of this paper is to provide policy guidelines to those who will play a role in the creation and success of the UAM ecosystem, and to serve as a baseline for enabling a goal-oriented, collaborative effort dedicated to resolving fundamental questions about UAM. From our perspective, the UAM ecosystem is expansive and includes community organizations, state and local authorities, public agencies, industry players (OEMs, suppliers, etc.), policymakers, researchers and investors, to name a few.

This paper is the first of its kind and, as such, aims to provide comprehensive policy recommendations for stakeholder groups over the next five years. Rather than acting as a technical deep dive into any particular subject, or as a prescriptive manual for UAM implementation, this paper highlights the critical actions that players in this space can take to progress toward UAM implementation.

UAM will comprise a network of on-demand hybrid or fully electric aircraft. The program's initial rollout will likely showcase secure vehicles, designed for a two to eight passenger capacity, on fixed routes along safely and securely regulated airspace. This system, supported by safe, secure and sustainable infrastructure, will position UAM to help communities deliver increased mobility, livability, and sustainable economic opportunities for their citizens.

Although UAM is on the horizon, many steps need to be taken to prepare for its emergence. Our research indicates a lack of sufficient focus both on policies to

support its future growth and comprehensive planning efforts to determine how and where UAM can fit into city and regional future mobility planning. Failure to plan for the future could cripple UAM before it has a chance to succeed. Therefore, it is critical that we outline policy recommendations now, to act as a guide for the next five years and help set the stage for this new mode of transportation.

If this effort is to be a first step toward building a policy consensus, we must start by asking the right questions:

- How do we leverage UAM to help cities and regions achieve their mobility and sustainability targets?
- How can we integrate UAM infrastructure in smart city planning?
- How should we govern the airspace in which UAM aircraft will operate?
- How will policymakers and industry leaders set the standards for aircraft safety?
- What kind of security and screening will keep UAM operations safe?

Establishing tangible answers for these questions must involve all stakeholders and may vary on a regional basis.

We have found **five major areas of policy opportunities and challenges** in moving the vision for UAM from concept to reality. They are, in order, "**Prioritizing Urban, Regional & Citizen Integration**," "**Managing UAM Traffic**," "**Building A Scalable Infrastructure**," "**Designing Robust Security**" and "**Developing UAM Vehicles**."

- **Prioritizing Urban, Regional & Citizen Integration.** We believe that local policymakers, communities and citizens, and businesses are the ultimate decision makers around how UAM can serve the distinct needs and goals of their communities. To start the conversation with cities and regions, we propose a set of action points that can be taken over the next five years to help regional and local authorities evaluate whether UAM is a fit for their communities and, if so, how it might become a vital element in improving local livability and regional economies.

- **Managing UAM Traffic.** The second chapter addresses the importance of cooperatively developing and defining air traffic management, and its governance, for future UAM operations. Action points for the next five years are outlined, and include strategies for establishing performance requirements and enabling seamless collaboration and safe operations for all actors in the traffic management system, as well as for designing representative test environments to increase the likelihood of real-world proof-of-concept trials.

- **Building A Scalable Infrastructure.** The infrastructure chapter covers requirements and policies that will need to be established over the next five years to enable the design of accessible and resilient UAM infrastructure for cities. The takeoff and landing infrastructure, or vertiport, should be shared among various mobility providers, should embody principles of sustainability and should enhance existing transportation systems. The necessary

physical, digital and energy infrastructure is to be anchored in the foundation for high-tech smart cities.

- **Designing Robust Security.** The security chapter calls for an overarching "UAM Security" domain to outline potential safety, security and privacy issues in the subdomains of vehicle, vertiport, operations center, business-to-customer and traffic management. In adapting and developing security policies for this budding space during the next five years, we encourage guidance from mature industries in determining roles, responsibilities and responses to protect against unauthorized action during eventual UAM operations.

- **Developing UAM Vehicles.** The final chapter covers the guiding principles for aircraft design and operations, and provides a five-year pathway toward identifying regulatory gaps in development, standards and certification for emerging technologies such as advanced automation. As UAM aircraft design matures, it is important that the industry begins safely testing in increasingly realistic environments and in alignment with anticipated standards.

These opportunities for UAM require the vision of **six primary stakeholder groups** critical to UAM planning and implementation. These stakeholders have different priorities depending on the development stage and area of concentration within UAM. Each chapter will begin with a visual indicator of each stakeholder's recommended level of involvement for that particular area.

The UAM industry has the potential to impact the lives of many in terms of accessibility, sustainability and economic development. Now is the time to lay the foundation required on every level of outreach, analysis, policy and technology integration, and eventually demonstrate the lasting value of UAM to society. The proverb, "Don't put the cart before the horse," has described those who approach serious endeavors with the wrong priorities and end up going nowhere. With a thoughtful approach and right policy considerations, we can ensure the introduction of UAM as a viable, if not vital, addition to the transportation infrastructure.

HOW TO READ THIS PAPER

UAM is a vast, complex and highly technical field. For this reason, we chose to focus on a narrow scope to ensure that the policy recommendations are accessible, interpretable and above all, actionable. See below for key guidelines on what readers should – and should not – expect to see in the pages to follow.

Five Year Scope

This is an ecosystem-level document that attempts to establish general consensus on critical elements of UAM implementation to consider and act upon over the next five years – from 2020 to 2025.

Policy Recommendations

This paper was written to serve as a high-level guide with general recommendations for policies and actions that will help make UAM a reality. It is not a prescriptive manual that offers sequential, step-by-step instructions for UAM implementation.

Solution Agnostic

In this paper, we offer a baseline untethered to any pathway to UAM implementation. Instead, we designed this document to inform and guide ecosystem actors as they grapple with the most urgent priorities for UAM implementation. Solutions are often geography-dependent, and our intention is for the content of the paper to be applicable globally.

Five Policy Areas

This paper's five primary chapters address five specific priority policy areas our research indicated to be the most critical in the short-term. These include, but are not limited to, community integration, traffic management, infrastructure, security and vehicle development.

Filling a Gap

With this paper, we have attempted to fill an existing gap in the current body of UAM research. This project was initiated after an extensive literature review pointed to a notable absence of resources on short-term policy actions and considerations for UAM implementation.

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Headway was made possible through the generous contributions of authors and organizations all around the world. Although certain statements in this document reflect the views of specific individual contributors, not all statements reflect the views of all contributors.

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CHAPTER 01

PRIORITIZING URBAN, REGIONAL AND CITIZEN INTEGRATION

COMMUNITY FIRST: BUILDING UAM ECOSYSTEMS TO SUIT LOCAL NEEDS

UAM development today is largely driven by private industry and public research agencies, but our research indicates that it will be citizens, business groups and policymakers who ultimately decide when and how UAM can provide safe, reliable transportation that meets the distinct needs of their communities. This chapter offers policy recommendations to be addressed over the next five years for assessing the ways in which UAM will impact particular cities, regions and citizens, and provides guidelines for amplifying its positive outcomes.

Efforts to gather public feedback on UAM have traditionally entailed early market forecasting, broad community acceptance surveys and studies examining public tolerance for vehicle safety, noise and pricing. This information may be useful to developers at a macro level, but we believe that policymakers will need a deeper

understanding of communities' specific urban planning goals to ensure that UAM implementation reflects each community's needs.

UAM has the potential to bring a variety of benefits to our cities and surrounding regions by filling in gaps of unmet demand in current transportation systems. However, addressing the breadth of issues and disparate interests of concerned parties will be a major challenge facing all UAM stakeholders. History offers numerous examples of ambitious transportation projects that have failed due to insufficient community engagement, and UAM won't necessarily be a good fit for every community. A diverse cross-section of communities and stakeholders must work together to determine whether UAM is right for them, and to ensure that the urban multimodal transportation systems they build are sustainable and resilient.

In this chapter, we propose a set of actions to be taken over the next five years that will help regional and local authorities evaluate the role of UAM in improving accessibility, sustainability and economic development. We also outline how UAM can be part of a broader urban mobility strategy. The set of actions for stakeholders to pursue includes:

A) Evaluating UAM Suitability	B) Communicating UAM's Advantages	C) Developing UAM Policy	D) Boost Economic Development with UAM
UAM's role in present and future mobility plans for cities and regions	Economic, environmental and livability considerations for UAM implementation	Near-term policy and legal requirements	UAM as a catalyst for economic growth

EVALUATING UAM SUITABILITY

UAM's role in future mobility plans for cities and regions

Urban and regional mobility needs are never static. Traffic patterns change; populations move; and businesses come and go. To implement UAM, it is crucial that governing bodies, policymakers, urban planners and other ecosystem stakeholders spend the next five years cultivating a detailed, up-to-date understanding of local mobility needs and emerging UAM technologies. These insights will provide them with the context they need to determine whether UAM implementation will be a suitable solution for mobility challenges in the cities and regions they oversee. In some cases, it may simply be infeasible to incorporate UAM into existing transportation systems. With processes in place for assessing mobility challenges, monitoring progress in UAM technology development and evaluating the suitability of UAM as a mobility solution, stakeholders can get an early start on integrating UAM into urban master planning efforts.

Action Point 1: Analyze the city's mobility challenges and gaps

Before governing bodies and policymakers can give due consideration to UAM as a mobility option for their city or region, they must perform a comprehensive assessment of local mobility needs and urban development priorities.

Methods and Recommendations:

- Conduct a comprehensive assessment of current transportation infrastructure, ensuring governing bodies have the data and technical capabilities needed to model their current multimodal transportation system, and to identify areas for improvement.
- Update city and regional master plans with relevant zoning considerations to accommodate UAM's potential impact on the current transportation system.
- Align needs and analysis at a regional level through collaboration between jurisdictional and transportation entities. (UAM services are likely to extend beyond city limits.)
- Define key targets and metrics to be used in evaluating local mobility systems (e.g., safety and security, capacity, sustainability and environmental goals, equitable access, benefits for local business development).
- Verify that all relevant agencies have sufficient personnel resources to evaluate new mobility modes.

Action Point 2: Study development timelines for UAM technology

To facilitate the timely implementation of UAM in their city or region, policymakers and planners should assess UAM technologies (i.e., review public demonstrations, trial programs, ongoing research, certification, etc.) as they evolve over the next five years.

Methods and Recommendations:

- Study UAM vehicle operational safety, reliability, capability and efficiency including airspace and traffic management developments.
- Review the latest strategies and best practices for UAM infrastructure design and their urban functionality.
- Investigate new security and operating requirements for UAM as they emerge across the burgeoning UAM ecosystem.
- Evaluate new solutions for UAM ground-based communication, surveillance systems and navigation as they are developed.

Action Point 3: Evaluate UAM technology as a mobility option

Urban planners can collaborate with civil aviation authorities (CAA) to enhance mobility planning efforts by incorporating the usage of airspace into a multimodal transportation system. UAM's low infrastructure footprint can help cities and regions achieve greater autonomy over how and where they want to connect in the medium- and long-term. However, we believe that UAM must be positioned as an integral part of a comprehensive mobility system if it is to be successful.

Methods and Recommendations:

- Conduct research and modeling to identify the specific mobility and livability challenges that UAM could address (e.g., access, cost, options, availability and reduction of commute time, as well as intra-urban connectivity and potential environmental impact).
- Assess how UAM can help urban planners meet targets for sustainability, land use, equitable access and resilience for emergency response and services.
- Create opportunities to develop new infrastructure and city services based on aggregated mobility data and an assessment of how new UAM infrastructure could improve overall mobility, combining UAM with other modes of transportation.
- Consider UAM as a flexible tool for urban planners to connect cities and surrounding regions, and as a means of renewing transportation systems in the region by building new connections.
- Leverage UAM to enable regional empowerment by redistributing activity to previously disconnected, underserved or remote areas. Activity redistribution would help reduce the need to commute long distances.

Action Point 4: Provision for UAM integration into urban master planning efforts

If UAM proves to be a viable component of mobility solutions for a particular city or region, urban planners and local officials can review relevant master planning documents and highlight any changes that would be needed for UAM implementation.

Methods and Recommendations:

- Consider how UAM would impact current urban mobility strategies (e.g., movement across sectors, citizen access to transportation infrastructure).
- Identify any changes that would be needed for state airport system plans.
- Determine how the local energy grid should be augmented or otherwise improved (e.g., energy demand, renewable energy provisioning, “smart grid” initiatives).
- Evaluate how best to integrate vertiports into the various development types (e.g., new urban areas, urban renewals, transit-oriented development projects).
- Diagnose areas of need for infrastructure investments (e.g., mixed-use infrastructure, funding mechanisms).
- Develop investment planning and rollout timelines – including stages for design, planning and public participation.

B) COMMUNICATING UAM'S ADVANTAGES

Sustainability, livability and economic considerations for UAM implementation

UAM has the potential to bring a variety of advantages to the communities that adopt it. Under the right circumstances, UAM could lead to quality of life improvements for local citizens, facilitate reductions in the transportation sector's overall environmental impacts, and could even serve as a potent revenue generator across regions. However, to realize these advantages, ecosystem stakeholders must make active efforts over the next five years to demonstrate the benefits of UAM to citizens, whose support and trust will be crucial if UAM implementation is to become a reality. At the same time, those stakeholders must also put mechanisms in place for fielding citizen feedback and incorporating it into the UAM planning process, ensuring that the UAM systems of the future fully reflect the needs and wants of the communities they serve. These are merely some of the first steps in the effort to reach public trust and demonstrate the benefits that UAM can bring to citizens and their community.

Action Point 1: Develop UAM integration/implementation scenarios to illustrate how UAM will improve citizen quality-of-life within a city or region

It's possible that UAM implementation could benefit both the environment and citizen quality of life. However, planners and other ecosystem stakeholders must ensure that citizens are aware of these potential benefits by partnering to create detailed integration/implementation scenarios – a mix of visual renderings, research and physical demonstrations showing how UAM systems will benefit the communities they serve.

Methods and Recommendations:

- Develop research reports that explore the ways in which UAM can add to a city's competitive strategy by attracting new businesses and fostering a high-quality, sustainable life for its citizens.
- Establish partnerships between industry, local officials and planners who will collaborate to create various interactive tools (e.g., showrooms, VR simulations) that will give local policy leaders and citizens an opportunity to see mockups of UAM.
- Develop and implement meaningful scenarios and physical demonstrations outlining UAM's potential to:
- Reorganize urban sectors to make cities more accessible for all by providing greater mobility to a diverse array of city inhabitants.
- Reduce dependency on personal vehicles and other on-ground transportation for long

distance commuting.

- Improve connectivity between urban and rural population centers.
- Shift attitudes towards shared/public transit, further encouraging reduced reliance on personal vehicles.
- Provide innovative and improved access to emergency services such as healthcare.

Ongoing Effort

The city of Toulouse (France), with its Vilagil project, aims to develop, test and integrate future Multimodal Mobility as a Service (MaaS) systems (ground and air), and the design required regulatory environment in collaboration with local industry partners. The project includes an IN-VITRO phase, where UAM technologies including VTOLs, infrastructure, and traffic management technologies are brought to maturation up to certification in a closed-off, safe and controlled test site environment. It is then followed by an IN-VIVO phase focused on urban integration in an active area, where UAM Systems are designed to be part of the Multimodal MaaS of electric and autonomous mobility View

Ingolstadt in Germany is set to follow a similar modal View

Action Point 2: Engage citizens to understand their wants, needs and concerns regarding UAM implementation

Major new urban mobility planning projects require discussion, education and above all, listening at the community level, so that planning efforts can be modified and improved in response to citizen concerns.

Methods and Recommendations:

- Integrate citizens' feedback into UAM implementation scenarios to co-create the distributed UAM system that best meets their needs.
- Engage with industry and community organizations to address local concerns such as safety and noise.
- Tailor strategies to address data privacy, data transparency, cybersecurity, sustainability, energy usage, and access.
- Supplement public engagement campaigns: consider town halls, surveys and focus groups, concentrating on under-served communities and stakeholders to ensure comprehensive inclusion.
- Publish findings of public engagement.
- Coordinate with lawmakers at the local, state, and federal levels.

Ongoing Efforts

Several preliminary UAM public perception studies (i.e., survey and focus groups) have been conducted to understand citizen's wants, needs and concerns:

Airbus UTM Community Perception study: Compiled public initial reactions to Urban Air Mobility and identified prioritized concern areas by surveying individuals in four distinct geographies: Los Angeles, Mexico City, New Zealand, and Switzerland View

Booz Allen Hamilton NASA UAM Market Study: Distributed a survey and conducted citizen focus groups encompassing five large U.S. metropolitan areas (Los Angeles, San Francisco, Houston, New York City, and Washington DC) to gauge initial public perceptions and societal barriers to UAM. View

McKinsey/Ascension/Crown NASA UAM Market Study: Included a survey of 2,500 consumers who detailed their thoughts on UAM, categorized major concerns, and was followed with general recommendations on strategies for dealing with public acceptance. View

Action Point 3: Position UAM as a champion for renewable energy and environmental sustainability

UAM could be an effective tool in the efforts made by planners and state/local officials' effort to meet transportation-related environmental sustainability targets. However, active measures must be taken to ensure its environmental benefits outweigh any potential negative impacts.

Methods and Recommendations:

- Anchor UAM to key UN Sustainable Development Goals (SDGs), particularly:
- UN Goal 3: "Ensure healthy lives and promote well-being for all at all ages."
- UN Goal 9: "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation."
- UN Goal 11: "Make cities and human settlements inclusive, safe, resilient and sustainable."
- Consolidate city energy and sustainability goals, initiatives, etc.; and investigate UAM's effects on consumption patterns across various energy sources. Questions to consider:
- How should planners approach grid infrastructure modification and active incorporation of renewable energy sources?
- Looking at specific cities around the world, how do environmental concerns shift across geographies?
- Study the impact of fully electric operations and unmanned operations on ozone and carbon emissions relative to current ground-based hybrid, electric and gasoline-powered vehicles.
- Model and quantify UAM environmental benefits while working to limit its potential negative impacts (e.g., effect on wildlife from increased air traffic).
- Identify opportunities to outfit UAM vehicles with measurement tools that would enable them to collect data as part of global efforts to advance micro climate sensing.

Action Point 4: Investigate financial mechanisms and revenue opportunities for UAM implementation at the city/region level

To ensure the resilience of the UAM system, governments, industry, investors, insurance providers and assessors must explore different models for UAM funding, such as Public-Private Partnerships (PPPs) or cost/revenue splitting agreements. These factors will likely vary significantly depending on geography, the structure of local government bodies, national and local laws, economic systems, city and regional resources, and the interests of private firms in the area.

Methods and Recommendations:

- Consider local airspace as a public resource and potential revenue source for the city/region.
- Research models of shared costs, shared revenues, and shared risk for infrastructure development and UAM operations.
- Identify successful PPP models in other industries and identify gaps
- Determine whether licensed access to the UAM transportation ecosystem should be regulated.

C) DEVELOPING UAM POLICY

Near-term policy and legal requirements

UAM requires cooperation between regulators and agencies at every level – from national to local – to define and de-conflict the essential roles and responsibilities of the UAM system. Even though civil aviation authorities are accustomed to dealing with all airspace issues, the integration of UAM will require city and regional stakeholders to take an active role in shaping some aspects of UAM policy development. These ecosystem stakeholders must work together to integrate UAM operations strategically and efficiently within the context of broader smart city planning efforts. They should also pay close attention to the wants and needs of the communities in which UAM will be implemented, working to get ahead of potential issues such noise and visual pollution, while also identifying opportunities for UAM to help the community achieve its goals.

Action Point 1: Define an overarching governance model

UAM implementation requires cooperation between regulators and agencies at every level, from national to local, to define and de-conflict roles and responsibilities. And even though civil aviation authorities are accustomed to dealing with all airspace issues, it is vital for the integration of UAM that city and regional stakeholders take an active role in shaping some aspects of UAM policy development.

Methods & Recommendations:

- National civil aviation authorities (CAAs) develop policies for preemptive jurisdiction airspace access and procedures . City and regional ity and regional policymakers and CAAs will work together to define time, manner and place of UAM operations.
- Determine whether local or regional authorities can collaborate with CAAs and policymakers on a framework that enables them to define permits for electric vertical take-off and landing (eVTOLs), traffic management providers and infrastructure. This framework should establish where, when and how UAM may operate in local areas, and cover issues such as the optimization of route structure, noise impact reduction, emergency response and infrastructure placement.
- Evaluate the federal/local agency structures that would be needed to enable UAM at scale (e.g., fragmented ownership over roles and responsibilities versus a new exclusive agency).

Action Point 2: Integrate UAM operations as a component of smart city planning

Planners must define policies across multiple disciplines to achieve successful UAM integration.v

Methods and Recommendations:

- Develop models for land use policy and zoning to facilitate the implementation of UAM infrastructure and flight corridors.
- Develop flight routes that are complementary to existing modes of transportation.
- Implement smart urban development through data-driven multimodal transportation planning and a broad aggregation of mobility data. This data must be protected to ensure the privacy of individuals, and should include a framework for the use of collected data by law enforcement where necessary for public safety.
- Add UAM considerations to other smart city infrastructure plans (e.g., ensure proper design of wireless communications networks' right of way to cover flight paths and not just roadways).

Ongoing Efforts

The Organization for International Economic Relations (OiER) is studying the integration of UAM Key Performance Indicators (KPIs) into the existing United for Smart Sustainable Smart Sustainable City (U4SSC) evaluation and methodology setup. This program aims to provide cities with the means for self-assessments, and to serve as a starting point for implementing concrete actions to improve a city's sustainability level and fulfillment of the SDGs. Dedicated KPIs will be developed to evaluate UAM's contribution in making cities smarter and more sustainable.
View

Action Point 3: Work proactively to tackle noise and visual pollution concerns through policy

Noise pollution and visual pollution are not new concepts, but the former has been a strong focus of the nascent UAS and UAM industries, while the latter has yet to be addressed formally with any standards. (The two do seem to be correlated, however, as data shows that individuals "hear an aircraft louder" if they can see it.) To secure public support for UAM, authorities, community groups, manufacturers and standards organizations must collaborate to minimize any noise or visual pollution generated by UAM.

Methods and Recommendations:

- Develop a comprehensive urban noise classification system.
- Use policy proactively to reduce noise levels and visual pollution in collaboration with industry and community groups (e.g., defining noise-related requirements for vertiports and vehicles, estimating

acceptable noise levels across different categories of land use such as residential, institutional, recreational, commercial, industrial and agricultural).

- Establish standards of analysis and reporting to be included in local urban plans for future UAM infrastructure development.
- Consider defining abatement noise measures (e.g., sound insulation), preventive measures (e.g., creation of noise overlay zones), and operational measures (e.g., flight-routing, hours of operation).
- Promote integration of UAM infrastructure with existing transportation infrastructure such as rail and road, and look for opportunities to place noisy infrastructure components where they will blend in with the pre-existing noise background.

Action Point 4: Identify viable UAM policy pathways in existing federal, state and local government frameworks

All stakeholders should take active leadership and organizational roles in assessing the livability and economic needs of the community, and the ways in which UAM can support community efforts to meet those goals.

Methods and Recommendations:

- Incorporate UAM into the transportation master plan for specific cities.
- Address the need for a clear organizational structure that clearly identifies which stakeholders are authorized to distribute UAM responsibilities, and which stakeholders will shoulder the liabilities under various circumstances (e.g., who does and funds what, and who is accountable for what).
- Consider the potential limitations of cities' financial and human resources when setting up organizational structures, to ensure the system is able to accommodate new modes. Engage proactively with local and municipal authorities to create reporting and enforcement mechanisms (e.g., monthly flight cards, complaint hotlines, etc.).

Ongoing Efforts

Airbus is collaborating with Bruit Parif, IFSTTAR, IAU, Onera and DGAC in order to optimize noise modeling tools and assess urban noise impact from eVTOLs, using legacy helicopter and eVTOL demonstrator noise data (Vahana, CityAirbus).This assessments and modeling will support public acceptance, psychoacoustic tests and regulation discussions to define noise acceptance criterion. View

D) BOOSTING ECONOMIC DEVELOPMENT WITH UAM

UAM as a catalyst for economic growth

The integration of UAM in the urban fabric has the potential to benefit a community at every level, from local businesses to citizens in search of employment opportunities, both directly and indirectly. However, local and regional stakeholders must take active measures to ensure that these benefits are realized to their full potential. For example, UAM can help cities and regions attract new forms of investment, but stakeholders must make strategic choices in the process of infrastructure development to ensure that investment funneled to the areas that need it most. As such, cities and regions should work closely with the business community ensure that UAM is thoughtfully implemented and positioned to become a long-lasting component in local and regional transportation systems.

Action Point 1: Identify market and job creation opportunities for the local community stemming from UAM

Local and regional stakeholders should take active measures to ensure that UAM's integration into the urban fabric brings economic benefits to the local community at every level.

Methods and Recommendations:

- DeIdentify employment generation opportunities in the new market segments that will emerge from the burgeoning UAM industry. For example:
- Traffic management services (e.g., software, hardware infrastructure, service provider, sales, applications)
- Aircraft manufacturing
- Flight service providers, fleet servicing, maintenance and repair
- Evaluate increased employment demand from incumbent industries (e.g., energy providers, communication and data services, construction for physical infrastructure).
- Foster workforce development and training programs for the public and private sector, working in collaboration with industry and academic institutions.
- Increase staffing for local and federal government as needed to effectively develop and oversee UAM operations.
- Model the increased economic activity that will be generated by organic growth in foot traffic for businesses situated near UAM vertiports.

Action Point 2: Outline the use of UAM to promote balanced and equitable urban development, and to attract new investment

Not only does UAM present an opportunity to improve mobility and livability in urban settings, but it also offers a chance to attract new forms of capital that could help reshape cities and their relations with surrounding regions.

Methods and Recommendations:

- Study strategies and approaches for using UAM to redistribute economic development efforts, broaden the distribution of activity and reinvigorate growth in targeted urban or regional areas.
- Quantify the impact of job creation and investment opportunities to targeted sectors through the introduction of UAM hubs and associated services (e.g., traffic management services, infrastructure development, maintenance and operation).
- Use model forecasting to validate the economic viability of UAM for a particular city and region.
- Ensure economic resilience of the UAM ecosystem through public-private collaboration and thoughtful modeling, planning and financing.
- Identify the organizational changes and job load shifts that will be needed in agencies and other government entities for UAM development and scaling, and develop an appropriate workforce training and hiring plan.
- Address concerns about UAM's potential impact on local businesses.

Action Point 3: Create a robust and resilient UAM business ecosystem to promote the region's growth

Cities and regions must actively collaborate with the business community to ensure that UAM is thoughtfully implemented, and to develop models that will enable it to become an enduring feature of the local economy and local transportation systems.

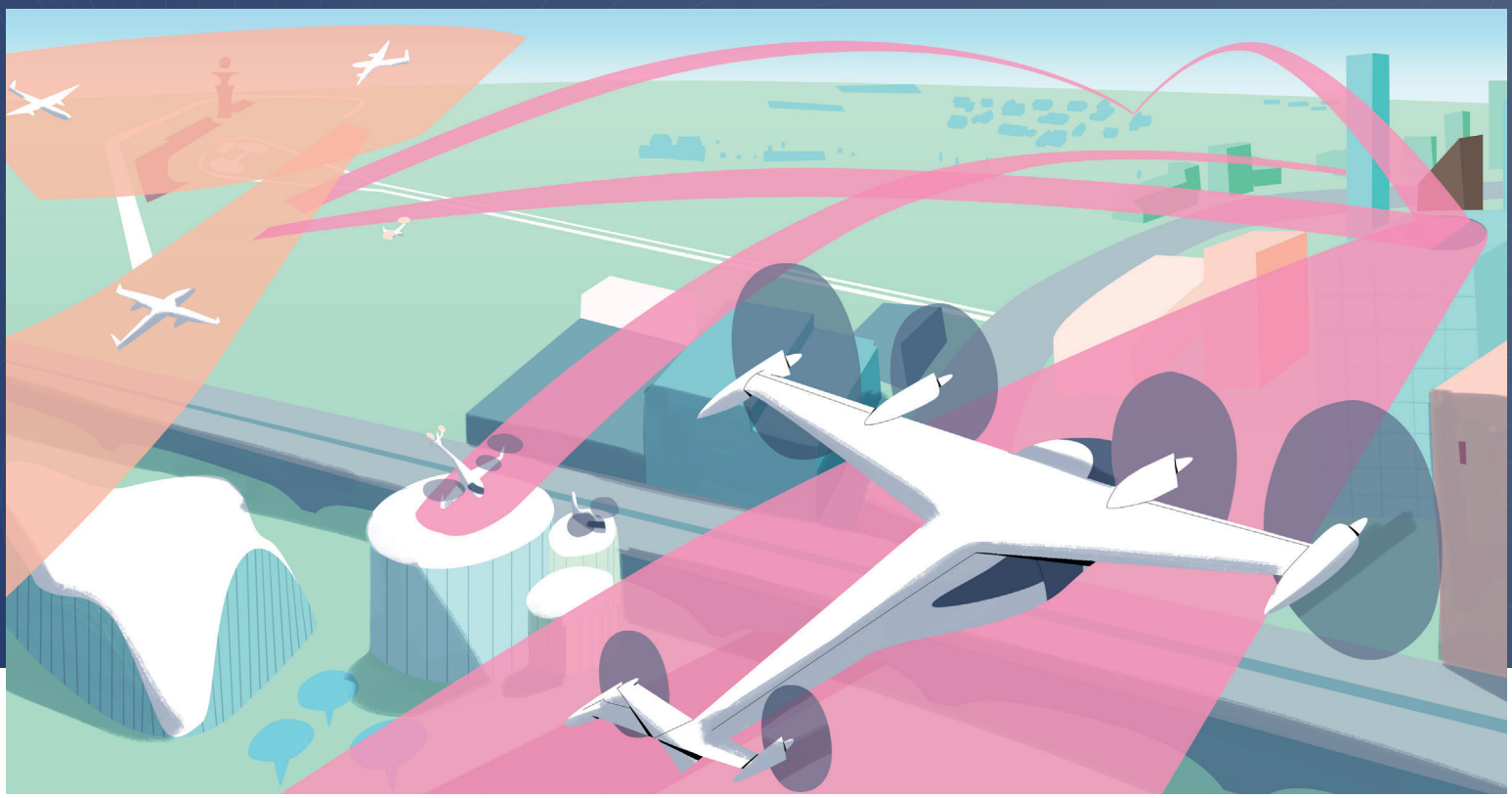
Methods and Recommendations:

- Form a standing business forum to build ties between UAM stakeholders (e.g., UAM industry, regulators, investors, service providers) and local businesses to shape business development in industries benefiting from UAM. The forum can comprise business development councils, owners of local businesses, municipal UAM liaisons and policymakers.

CHAPTER 02

MANAGING UAM TRAFFIC

SAFE SKIES: LAYING THE GROUNDWORK FOR SAFE AND SCALABLE AIRSPACE TRAFFIC MANAGEMENT



To scale UAM operations in the future, we must first define and develop an interoperable airspace system where new vehicles can safely and cooperatively integrate with existing aircraft. This chapter examines how Civil Aviation Authorities (CAAs) and industry stakeholders can address questions around interoperability, governance, requirements, testing and deployment over the next five years to ensure current and future traffic management systems can safely support UAM operations at scale.

Globally, there are multiple efforts underway to modernize the current air traffic management (ATM) system and safely integrate unmanned aircraft systems (UAS) into our skies. For example, in the U.S., the FAA, NASA and other government agencies are enabling UAS integration through public-private partnerships, research on Unmanned

Traffic Management[1] (UTM) systems, and the use of new technologies that allow the government to share UAS airspace data with industry partners. In Europe, the primary work focus is U-Space where key entities including EASA, EUROCONTROL and the SESAR Joint Undertaking are defining and testing airspace services to integrate Europe's growing UAS operations safely into European airspace. ICAO, through the UAS Advisory Group, has published their vision of a globally harmonized UTM framework.[2]

Initial low-volume UAM operations might be adequately managed by traditional ATM systems. However, this will not be the case for UAM at scale, which will require a much higher level of automation. Depending on the scope and type of operations, UTM services currently being developed for small UAS can evolve to enable UAM at scale. In this chapter, we outline the key areas of focus over the next five years to enable the safe integration of UAM, assuming an integrated and modernized airspace management system in the future. These key areas of focus include:

A) Enabling Interoperability for UAM Traffic

Ensure all types of UAM vehicles are safely integrated into an evolving traffic management system

B) Establishing Governance in UAM Traffic

Define traffic management and airspace governance models to support UAM operations

C) Determining Traffic Management Requirements

Establish performance requirements and regulations to enable seamless collaboration and safe UAM operations for all stakeholders in the traffic management system

D) Establishing Test Environments and Facilitating Deployment

Design representative test environments and provide traffic management stakeholders with a viable pathway for supporting UAM from testing to preliminary operations

1 For consistency we use the term UTM in this document. UTM in Europe is referred to as U-Space

2 ICAO Unmanned Aircraft Systems Traffic Management (UTM) – A Common Framework with Core Principles for Global Harmonization Edition 2,
https://www.icao.int/safety/UA/Documents/UTM-Framework%20Edition%202.pdf

A) ENABLING INTEROPERABILITY FOR UAM TRAFFIC

Ensure all types of UAM vehicles are safely integrated into an evolving traffic management system

Given the diverse roster of vehicle manufacturers and traffic management suppliers who will help make UAM a reality, it is vital to ensure interoperability across products developed by these ecosystem stakeholders. A great deal of work must be done over the next five years to build a consensus on the scope of modernized traffic management systems, to develop a timeline for improving functionality in automated traffic management systems, and to plan for the integration of UAS traffic management systems with modern day ATM. A failure to do so may leave UAM insufficiently supported for long-term viability. Action points include:

Action Point 1: Gain consensus on the scope of a modernized traffic management system

In an environment that already includes commercial and general aviation, as well as UAS (drones), managing traffic that is made up of a diverse array of UAM vehicles will require a new set of services. The services and capabilities that will be required to enable safe operations must be comprehensively defined to establish appropriate standards and certification pathways, most of which do not yet exist.

Recommendations:

- Identify the various functions and capabilities that are needed to manage UAM in the airspace (e.g., information systems and services, data-sharing, data security, flight planning, emergency response protocols, services covering meteorology, and requirements for pre-, mid- and post-flight).
- Establish guiding principles around system performance requirements to enable interoperability across vehicles, environments and use cases under the umbrella of ICAO.
- Consider requirements for traffic management systems that will support vehicles operating across all levels of automation.
- Identify the key challenges of introducing human-centered AI into aircraft and traffic management operations, particularly as relates to certification and regulation.

Action Point 2: Develop a timeline for advancing functionality in automated traffic management systems

To scale operations over time, systems developers and policymakers must work in consultation with academic and government researchers or private entities to map out incremental steps toward automation in the systems that manage air traffic.

Recommendations:

- Identify milestones to track the development of automated traffic management. Broadly, these stages are as follows:
  - » Supplementary data services
  - » Limited decision-making control with supervision
  - » Automated mission management with human oversight
  - » Fully automated mission planning
- Identify traffic management candidates (location and provider) for early trial projects.
-

Action Point 3: Map out the integration of UAS traffic management systems and services (e.g., UTM/U-space) and ATM (with general and commercial aviation)

An integrated airspace is key to avoiding potential conflicts between UAM and manned aviation operations over airspace access. A failure to plan for this integration may leave UAM insufficiently supported for long-term viability.

Recommendations:

- Identify the ATM systems and permissions that are likely to benefit from or be otherwise impacted by automation (e.g., surveillance, route-planning, deconfliction, information management, take-off/ landing permissions and access).
- Consider the extent of integration between UTM and ATM with the possibility of shared services. Identify and combine requirements for airspace rules and procedures in low altitude urban operations
- Prepare an ICAO working paper on matters of UAM, including airspace integration, for the 2022 Assembly.

ICAO provided a framework, principles and list of services for a typical UTM system that many member states are considering in the “A Common Framework with Core Principles for Global Harmonization” document.

The Global UTM Association (GUTMA) released a document describing an overall high-level UTM architecture for all types of UAS operations (VLOS, EVLOS and BVLOS), RPAS (piloted) and autonomous unmanned aircraft (link).

In Europe, the Single European Sky ATM Research Joint Undertaking (SESAR) U-Space concept is a public private partnership launched to enable a framework for airspace and traffic management to support large numbers of highly-automated unmanned aircraft systems access to airspace (link).

B) ESTABLISHING GOVERNANCE IN UAM TRAFFIC

Define traffic management and airspace governance models to support UAM operations

With increasing clarity on the scope of modernized traffic management services, their functions and integration, there is an important conversation to be had about the role that local or regional authorities must play in the realm of airspace governance for certain jurisdictions where the situation may be ambiguous. Over the next five years, the industry must outline specific roles and responsibilities for each department, agency and any other related entities to establish a system that operates with the highest levels of safety, and to make it possible to anticipate relevant funding implications. Action points include:

Action Point 1: Outline the roles and responsibilities of local, regional and national stakeholders in formalizing and delivering airspace management services

Governance and authority structure must be established at an early stage for each stakeholder in the traffic management chain and across all airspace classifications. This will ensure that stakeholders are well-positioned to develop systems and services that will safely reach maturity.

Recommendations:

- Analyze differences in governance structures: centralized vs. distributed, types of funding mandates, etc.
- Outline key roles in the traffic management ecosystem and map interactions between the various stakeholders (e.g., service providers, eVTOL operators, local and federal regulators).
- Consider how an integrated airspace can provide for multiple service providers, and determine who will authorize new service providers.

Action Point 2: Define new aviation safety critical services

A key priority of the governance structure will be to determine the balance of duties between UAM vehicles and traffic management providers with respect to safety critical services, thus ensuring operational safety.

Recommendations:

- Establish protocols for communication, navigation and surveillance (CNS), deconfliction, collision avoidance and emergency response.
- Outline advantages and disadvantages of assigning safety-critical services in vehicles vs. traffic management systems (e.g., vehicle requirements for ADS-B and associated TIS-B/FIS-B systems, the need for a higher capacity system that precludes the use of ADS-B due to spectrum saturation).
- Illustrate how responsibility designation will affect certification for the overall UAM system (e.g., vehicle and traffic management).
- Include matters of UAM liability in the proposed ICAO UAM Working Paper for the 2022 Assembly.

Action Point 3: Explore traffic management business cases and funding models

Securing self-sustaining funding models is essential for a modernized traffic management system's development and operations, as well as its long-term maintenance.

Recommendations:

- Assess existing funding models and their applicability to UAM, as well as their potential impacts.
- Discuss which government funding models are available and applicable to the task of evolving airspace management capabilities to accommodate UAS/UAM, including the use of airspace as a potential public revenue source for cities and regions.
- Explore supplementary funding models, such as:
  - National funding (e.g., trusts, direct funding)
  - Local or regional funding (e.g., taxes on services or operators)
  - Private funding (e.g., commercial system)
  - Hybrid funding (e.g., PPPs, privately operated public utility)
- Determine whether operators and user-based funding models can cover UAM's costs – either entirely or in part. If the costs are too high, how does that affect scalability and deployment across many cities with varying augmentation infrastructure?
- Outline the necessary oversight frameworks for various funding models.

C) DETERMINING TRAFFIC MANAGEMENT REQUIREMENTS

Establish performance requirements and regulations to enable seamless collaboration and safe operations for all stakeholders in the traffic management system

Safe aircraft operations in any airspace or mission will require equally safe interactions between all traffic management systems. As these systems – and their integration of UAM – will evolve over the course of many years, fair access, standards and performance thresholds must be established from the outset. This includes not only requirements related to communication and navigation and the corresponding infrastructure, but also guidelines for the marketplace of traffic management service suppliers that will build out supplementary services. Action points include:

Action Point 1: Study requirements for communication systems and traffic management infrastructure, including those pertaining to communication and navigation

Stakeholders must answer a series of key questions before they can establish appropriate protocols and requirements for communication and data-sharing between vehicles, operators, fleet managers, service suppliers and other parties.

Methods & Recommendations:

- Convene a broad coalition of stakeholders – including policymakers, subsystem suppliers, OEMs and standards bodies – to answer open questions such as:
  - How will capacity and bandwidth issues change as operations scale?
  - How will system procedures compensate for loss of communications with ATC, local operations or other vehicles?
  - Who is liable for what and under what circumstances?
  - What are the advantages and disadvantages of using reserved aviation vs. commercial spectrum?
- Define requirements and protocols for communications and data sharing, and establish requirements for vehicle-to-vehicle and vehicle-to-USS[1] (UTM Service Supplier).

The American National Standards Institute (ANSI) standardization roadmap outlines published and in-development standards for unmanned aircraft systems including those to determine requirements for UTM. View

1 *The equivalent in Europe is a U-Space Service Supplier (USP)*

Action Point 2: Assess navigation performance and surveillance requirements necessary to scale UAM operations safely

Navigation performance specifications have yet to be defined for UAM – an issue that is especially pressing for UAM use cases that demand precision navigation (e.g., take-off and landing in low visibility conditions, or flying in multipath conditions). Standards related to compatibility in communication architectures and interactions across the different types of operations must also be addressed to enable precision navigation throughout the ecosystem.

Recommendations:

- To enable consistent precision navigation across all UAM use cases, stakeholders must consider the following questions:
  - » What are the most viable methods of augmenting GNSS signals (e.g., to address increased precision requirements in urban areas)?
  - » Is GNSS capable of supporting low altitude UAM operations in city environments (e.g., urban canyon)?
  - » Which navigation and surveillance equipment (e.g., collision avoidance, detect and avoid (DAA)) may be located onboard or offboard in varying proportions? Will there be compatibility issues with differing architectures or will there be a universal specification for all designs and platforms?
  - » Will there be different separation standards for interactions between piloted, unmanned, remote and/or automated operations?

Action Point 3: Establish baseline performance requirements for UTM infrastructure

Navigation, surveillance and communication requirements ultimately represent a set of physical and digital infrastructure problems that need to be solved – either through the adaptation of legacy infrastructure, or with the development of new infrastructure.

Recommendations:

- Identify the gaps between existing ATM infrastructure and the traffic management infrastructure that will be needed to enable UAM.
- Assess requirements in key areas of physical infrastructure (e.g., ground-based surveillance stations, operational control centers, information management hub facilities) and digital infrastructure (e.g., communications spectra, data storage, information management platforms).
- Establish rules and procedures for facilitating the interface between traffic management infrastructure and city mobility protocols by allowing both air navigation service providers (ANSPs) and other service providers to share mobility data, while also ensuring that data privacy and data security are maintained.
- Ensure that any new infrastructure works safely and in harmony with existing infrastructure wherever possible.

Action Point 4: Outline procedures, rules and service provisions for operational interactions between current ATM and next-generation management systems

From the start, UAM vehicles will coexist and operate close to or in airspace being used for commercial

aviation, general aviation (GA), and UAS aircraft. It is vital that stakeholders work to ensure effective data exchange between different platforms and operations.

Recommendations:

- Determine data sharing standards and necessary regulations, including airspace classification for UAS/UAM operations and clear rules for overlapping operations.
- Develop rules and technology for transitioning from ATM-controlled airspace to low-altitude management airspace systems (and vice versa) with explicit procedures for governing conflicts or emergency situations.
- Align risk profiles and risk assessment methodology between manned and unmanned aircraft operating in shared airspace.
- Develop a regulatory roadmap for certifying AI operations.
- Establish baseline provisions and requirements for data-sharing and exchange between ANSPs and USSs (e.g., authoritative and validated common digital data sources).

Action Point 5: Ensure equitable access for all traffic management providers and airspace users

It is important to foster equitable access to urban airspace for all traffic management providers. Each region will likely include several providers, with each of those providers representing a specific area of expertise (e.g., weather, path planning, collision avoidance), and operators will need to know which services are supplied by each of the various traffic management providers. It is also important to foster equitable urban airspace access for all operators.

The diverse array of operation types that will seek this access must be accommodated in a way that prevents the monopolization of any resources, and which is considered fair by all users, promoting greater cooperation.

Recommendations:

- Determine tactics that various proposed modernized traffic management models can use to provide opportunities for new players (small, niche, etc.).
- Engage with prospective players (e.g., companies developing traffic management software) about barriers in bringing new offerings to market.
- Ensure that the interoperability requirements of USS do not create unreasonable barriers to entry.
- Leverage work from other sectors and industry collaboration forums to ensure equitable airspace access to all users (e.g., IATA UAS Think Tank, FAA Access to Airspace Aviation Rulemaking Committee (ARC)).
- Ensure that proposed approaches to traffic management and associated algorithms for resource allocation prevent operators from monopolizing resources. Approaches should also penalize untruthful behavior aimed at gaining an advantage at the expense of other operators.
- Establishing Test Environments and Facilitating Deployment
- Design representative test environments and provide traffic management stakeholders with a viable pathway for supporting UAM from testing to preliminary operations

D) ESTABLISHING TEST ENVIRONMENTS AND FACILITATING DEPLOYMENT

Design representative test environments and provide traffic management stakeholders with a viable pathway for supporting UAM from testing to preliminary operations

To commence UAM operations, traffic management systems developers will need to demonstrate the effectiveness of equipment, procedures and processes for safely managing urban air traffic. This will require extensive testing and evaluation before commercial UAM operations begin. Additionally, that testing must take place in representative environments that mimic real-world operational situations, with regulators granting waivers to test critical uncertified traffic management systems. Performance data from these early tests will inform the standards and policies that will be developed for traffic management. Action points include:

Action Point 1: Assess current system infrastructure for suitability in supporting traffic management test operations

After determining suitability of systems for UAM operations, some components of the current ATM and communications infrastructure may be usable for managing UAM traffic.

Recommendations:

- Define the components of an ATM system that can support UAM ground operations.
- Identify technical issues related to capacity, functionality and adaptability.
- Assess remaining policy gaps for traffic management supporting UAM operations.
- Explore suitability of existing UAS test sites for traffic management systems testing.

Action Point 2: Define validation requirements in next-generation traffic management prototype systems

Proponents of UAM will need to meet certain thresholds to demonstrate appropriate levels of safety while advancing necessary functionalities in automated traffic management systems.

Recommendations:

- Create an end-to-end path for system acceptance in increasingly representative testing environments.
- Provision for initial flight operations with or without onboard human pilots.
- Foster improved communication between industry and regulators.
- Use prototype systems to define baseline performance characteristics for advancing functionality in automated traffic management systems.
- Investigate the possibility of simulated testing as a short-term solution for testing and demonstrating system safety
- Ensure validation is grounded in realistic assessment of system capabilities.

Action Point 3: Provide waivers to enable representative environment testing for modernized traffic management technologies and set the stage for early trial operations

Until a system is put in place for UAM vehicle certification, traffic management services providers will need waivers to move forward with testing, which is critical to systems development.

Use narrowly-defined waivers or exemptions to permit the safe testing of uncertified systems and equipment for data gathering purposes.

Align CAAs and systems developers on target objectives for programs testing increasingly advanced automated traffic management systems

Utilize environments that are similar to expected operations, but less complex (e.g., suburbs instead of dense urban cores).

Align industry, regulators and local officials on a timeline for the first limited trial operations.

Frame authorization and letter of agreement (LOA) process with CAAs and/or ANSPs.

Action Point 4: Use data from testing phases to better shape standards and requirements for operation-ready systems

As systems, procedures and infrastructures are tested, refined and validated, stakeholders can move forward into limited commercial trial operations in select

In February 2020, Airbus signed an agreement with the Civil Aviation Authority of Singapore (CAAS). Airbus and CAAS will collaborate to define and develop an initial UAM service with an Unmanned Aircraft System. The parties will specifically work together to realise the UTM system and services to support the initial use-case. View

NASA signed agreements under the Space Act with 17 companies to participate in technology demonstrations for the Urban Air Mobility (UAM) Grand Challenge. The Challenge will include testing UAM traffic management services in airspace simulations.

locations – leveraging best practices and other lessons taken from the testing process.

- Validate and verify accuracy of simulation models.
- Identify gaps in regulatory requirements to inform waiver needs for trial program operations.
- Measure performance data of representative vehicle systems.
- Sense, avoid and deconflict participating and non-participating traffic.

Conclusion

For UAM to be considered a viable transportation option for citizens, industry stakeholders must collaborate on numerous endeavors – such as safety requirements, communication protocols and data exchanges – towards an integrated and modernized airspace management system. This includes efforts to define parameters, outline procedures and align policy to enable UAM at scale.

CHAPTER 03

BUILDING A SCALABLE INFRASTRUCTURE

INTELLIGENT MOBILITY: INTEGRATING RESILIENT, SCALABLE AND ACCESSIBLE UAM

It is now widely recognized among transportation and development experts that citizen mobility habits must shift if the world is to achieve a more sustainable and resilient urban future. Mobility is a core function of individual activity – daily commuting, travel for leisure, etc. – and has wide-ranging effects on urban development. Innovative shared-mobility services like UAM can help bring about sensible changes to citizen movement patterns, reducing the need for existing modes of transportation. However, efforts to implement new modes of transportation have historically been challenged by substantial hurdles. This chapter offers action steps for UAM infrastructure planning and development over the next five years.

In overseeing UAM's integration into cities, there are three types of infrastructure that must be addressed: physical to support vehicle takeoff and landing (i.e., aerodromes,

airports and heliports), digital (to support traffic modeling and monitoring) and energy (to power electric or hybrid VTOLs). UAM should serve dense, compact and mixed-use urban environments, and should be strategically distributed across regions. Landing and takeoff pads for VTOLs (i.e., vertiports) can serve as data and communications hubs for city-wide grids, and as links in a sustainable energy infrastructure – making them an essential element in new urban areas, urban renewal, and transit-oriented development projects. The number and accessibility of these vertiports will have a significant impact on the adoption rate of UAM within a city, and will influence the extent to which that city reaps the benefits of UAM.

This means that realizing improvements for urban mobility will require careful infrastructure planning for physical spaces, digital services and energy utilization. From a digital perspective, it will be important to make it easy for transportation authorities and mobility stakeholders to share data and collaborate on infrastructure design. The systems will be compact, in accordance with sustainable urban transportation planning principles, and flexible in their use of vehicle technology. These qualities will ensure that UAM infrastructure enhances existing urban transportation's usefulness while supporting multimodal connections. Strategic vertiport placement and use of existing infrastructure will also be key for noise mitigation strategies.

A) Aligning High-Level UAM Goals With Broader Urban Planning	B) Defining Requirements Necessary For UAM Infrastructure	C) Outlining Policy Solutions For UAM Integration	D) Coordinating UAM Infrastructure
Frame UAM infrastructure as a component of urban mobility master planning	Establish the key considerations in implementing UAM infrastructure	Develop policy mechanisms and plans to bring UAM to the existing urban infrastructure	Recognize the logistical and practical considerations in developing and implementing UAM infrastructure

In this chapter, we provide a path forward that takes advantage of ongoing efforts in smart-city infrastructure planning to better integrate UAM as a key feature of future urban mobility. To achieve this vision, in the next five years we must focus on:

A) ALIGNING HIGH-LEVEL UAM GOALS WITH BROADER URBAN PLANNING

Frame UAM infrastructure as a component of urban mobility master planning

UAM will be part of a broader, multimodal transportation network that includes air, ground and water, so its infrastructure needs cannot be considered in isolation. Instead, stakeholders must examine existing transportation infrastructure, as well as future development plans, and seek opportunities to incorporate UAM. Ideally, UAM infrastructure should be designed to be vehicle-agnostic so that it can be shared among a variety of operators and across different modes of transportation, in order to meet the sustainability goals of the region. Action points include:

Action Point 1: Assess existing infrastructure (physical, digital and energy) and challenges related to urban development

Recognizing infrastructure challenges, and the importance of impact assessments associated with urban development and mobility strategy are essential to support UAM and must be accomplished in conjunction with other urban transportation infrastructure elements.

Recommendations:

- Assess challenges associated with existing physical infrastructure development in urban areas, including space limitations and placement. Consider how UAM might integrate with other modes of transportation, such as incorporating UAM analysis into airport planning processes.
- Assess the region's ability to model, monitor and manage the flow of digital mobility information.
- Assess the region's energy infrastructure, including:
    - The city's ability to model energy usage, efficiency, production and environmental impact
    - The current energy mix and opportunities for local renewables development that could support UAM
    - The anticipated future energy needs for urban mobility, based on aggregate usage data and energy production information. Predictions can inform the strategies cities choose regarding access to charging stations, grid enhancements, the distribution of energy hubs, etc.

Action Point 2: Frame high-level development goals for UAM infrastructure

While assessing urban infrastructure challenges, UAM developers must also align on specific high-level design and development goals to ensure that UAM is responsibly implemented

Recommendations:

- Aim to build UAM infrastructure that follows sustainable urban transportation planning principles, including the objectives outlined in the UN Sustainable Development Goals (SDGs) related to mobility and liveability (particularly goals 3,9 and 11).
- Align on the design of vehicle-agnostic infrastructure that can be shared among fleet operators and support VTOLs of varying power sources (e.g., hydrogen, electric, kerosene), levels of automation (e.g., piloted, remote-piloted, fully-automated), and capacity (between 1 and 9 passengers).
- Create digital and telecommunication infrastructure that can be shared among traffic management providers.
- Source renewable energy at the local level and attempt carbon neutral operations.
- Work toward creating a multifunctional and compact design, considering shared use options and strategic placement for energy sources (air and ground transport), data centers, operations centers and maintenance facilities.
- Foster equitable access through design and placement, considering economic growth potential.

Ongoing efforts

Inspiration for guiding principles can be taken from the United Nations (UN) Sustainable Development Goals for Innovative Infrastructure View

ERRAC's urban mobility working group have produced a roadmap for integrated urban mobility infrastructure, though their scope is limited to road transportation. However, they have outlined productive strategies and pathways toward effective integration of urban mobility modes. This work was completed alongside ERTRAC and ALICE. View

Deloitte has produced a comprehensive report on the value of a unified digital ecosystem to support emerging and unified mobility frameworks View

Action Point 3: Ensure UAM infrastructure enhances the functionality of existing urban transportation networks

In addition to supporting UAM services, the implementation of UAM infrastructure also presents opportunities to augment existing transportation infrastructure, promote shared use, and pave the way for a multimodal transportation network.

Recommendations:

- Strive to increase the functionality of existing transportation infrastructure (e.g., by embedding vertiports at train stations, highways and intersections, or by leveraging airspace above roadways for flight routes). UAM implementation could therefore serve to reinforce the use of main transports, by enabling greater catchment areas.
- Leverage underutilized helipads and general aviation airports, both of

which will likely serve as early sites for UAM operations and as representative test environments for larger airports.

- Strive to create multimodal facilities that serve different components of the transportation network (rail, water, underground, etc.) in order to create a seamless passenger journey experience.
- Study how vertiports could enhance the resilience and capacity of the existing energy and data grid – particularly in terms of their ability to function as storage and relay nodes for local energy and data
- Collaborate with all stakeholders in the region's mobility ecosystem to align on shared goals and solutions.

(1) Accurate modeling for UAM is dependent upon OEM release of vehicle power specifications. Type certificate data sheets (TCDS) will provide precise aircraft specifications.

B) DEFINING REQUIREMENTS NECESSARY FOR UAM INFRASTRUCTURE

Establish the key considerations in implementing UAM infrastructure

UAM infrastructure needs will span three main categories: physical, digital and energy. In approaching infrastructure design, stakeholders should spend the five years ahead seeking to determine the baseline requirements and best practices across these areas. For digital infrastructure in particular, UAM should integrate well with the broader transportation network, allowing for data sharing and other collaborative activities. Additionally, stakeholders should consider the potential impact of any UAM infrastructure on local communities, working to ensure that it is both functional and beneficial for those communities. Action points include:

Action Point 1: Determine vertiport facility requirements

The primary concerns of any vertiport development should include safety, noise mitigation, environmental impact and land use.

Recommendations:

- Ensure vertiports are compatible with local land use types and zoning laws.
- Consider key environmental impacts of vertiport development over the next five years, including:
  - Noise mitigation and minimizing the number of routes over densely populated areas
  - Alignment with UN Sustainable Development Goals (SDGs) and environmental standards
  - Sustainability in both construction and energy production, supply, storage, recycling and usage
  - Integration with existing ATM routes
- Consider key vertiport performance characteristics over the next five years, including:
  - Baseline functional requirements (e.g., communications, data, addressing potential hazards)
  - Structural and dimensional requirements (e.g., structural integrity studies for helipad repurposing)
  - A high degree of multimodality

- Standardized charging requirements to ensure compatibility across a broad variety of vehicles
- Safety compliance and defined emergency procedures

- Evaluate potential logistical constraints like access, throughput, vertipad turnover and charging times.
- Explore vertiport solutions that help simplify infrastructure across different modes of transportation. An example is scaling concepts such as One ID to simplify security for passengers.

Past & Ongoing efforts

The National Air Transportation Association (NATA) have published an extensive report on the operational considerations for Vertiport infrastructure in support of UAM efforts

View

Action Point 2: Determine requirements for digital infrastructure

Digital infrastructure will impact multiple areas of UAM operations and should be designed with an eye toward compatibility and collaboration with other ecosystem stakeholders. It will also play an important role as cities and regions look to govern mobility activities.

Recommendations:

- Establish key details for an digital mobility platform, including data sharing practices and protocols, shared application programming interfaces (APIs) and a common application development ecosystem.
- Create a standardized set of procedures and formats for data sharing (covering both how to share and what to share), as well as standard reference systems, for collaborative mobility planning.
- Explore how UAM can expand digital networks in urban environments through the additional data hubs that will be needed for UAM operations.

Action Point 3: Engage with local communities to ensure that UAM infrastructure is designed to serve their needs

It's important to establish a venue through which citizens and other local stakeholders can express their needs and concerns, which should be reflected in the design and implementation of UAM infrastructure.

Recommendations:

- Broaden UAM infrastructure development requirements to extend beyond basic functionality and to include benefits for nearby communities.
- Work to build a dialogue around community expectations and needs for UAM infrastructure – from inception through to eventual operation – and embed that knowledge into rollout.
- Co-create guidelines with the community for infrastructure placement that accounts for various potential impacts (e.g., mobility improvements versus noise considerations).
- Consider passenger pickup and dropoff zones when selecting vertiport sites, especially if passengers might use other transportation modes to access the vertiport.
- Design vertiports to help bolster the local economy and to be a part of a city's social functions.
- Aim for new infrastructure to provide equitable access for underserved communities (e.g., bringing new consumers to local businesses or connecting people to new job opportunities in nearby areas).

2. https://www.iata.org/whatwedo/passenger/Pages/one-id.aspx

C) OUTLINING POLICY SOLUTIONS FOR UAM INTEGRATION

Develop policy mechanisms to bring UAM to urban infrastructure

Infrastructure will play an important role in the operation and governance of UAM, which is why policy must guide its implementation. For instance, being able to exchange mobility data will be critical for local authorities to issue permits to UAM operators; therefore, having a well-designed digital infrastructure is key. Policy can also help define how infrastructure is funded and operated, as well as ensuring that it meets predetermined sustainability and livability goals. Action points include:

Action Point 1: Establish the right digital infrastructure to allow cities and relevant authorities to govern stakeholders in the mobility market

UAM is just one component of a much larger transportation network, which means that its usage data and inventory of vehicles will need to be incorporated, modeled and monitored on a shared digital platform that includes all other transportation modes within the broader Smart City mobility ecosystem.

Recommendations:

- Establish a standard mobility simulation model using the latest city and population data, and ensure that mobility service providers are granted access so they can use the simulation model as a reference.
- Release a standard API, enabling transportation authorities to aggregate all mobility services into a single reference digital platform: “Total Mobility Provider” (as per the The International Association of Public Transport recommendations).
- Govern access to the mobility ecosystem under either the local transportation authority or under whomever is delegated that responsibility.
- Ensure usage data from mobility stakeholders is shared with transportation authorities in a standardized way, and made accessible to other mobility suppliers via an established standard market.
- Create a two-way flow of data by enabling transportation authorities to use the digital platform to share key information with mobility stakeholders (to assist them in their service offerings).
- Use the digital infrastructure as a tool for private mobility suppliers and public authorities in crafting policies and regulations.

Action Point 2: Define the relationship between city or regional authorities and infrastructure developers and operators

Cities and regions have an opportunity to shape cooperative agreements with outside parties to guide the financing, development and operation of critical infrastructure.

Recommendations:

- Determine who will pay for new infrastructure development (e.g., taxpayers, private investors, etc.).
    - » Early stage development will likely be funded by private investors, although cities could provide grants or allocate tax dollars to cover costs.
    - » Cities can develop attractive policies and investment frameworks to facilitate third-party agreements and encourage private investment.
    - » Involve energy companies in long-term infrastructure investments.
- Foster public-private collaboration.
    - » Consider the permitting process for land use, ownership and zoning.
    - » Define technology needs for digital and energy infrastructure, and encourage infrastructure sharing among providers.
- Decide who will operate the infrastructure on a daily basis.
    - » One option is an FBO model.
    - » In the short-term, stakeholders can look to the top airports in the world for best practices in operations, multimodality and connectivity.
- Consider how transportation authorities (or other local government officials) will enforce compliance with standards for mobility infrastructure.
    - » Establish a framework for compliance and oversight during both construction and operation.

Action Point 3: Use policy to ensure UAM infrastructure helps achieve the liveability and sustainability goals of the city or region

Policy will play an important role in keeping infrastructure development and operation in line with stated goals listed in Section A, Action Point 2.

Previous and Ongoing Efforts

The City of Los Angeles started the Mobility Data Specification (MDS) in 2018, an open source tool anchored in common language for data sharing and formatting through the use of application Programming Interfaces (APIs). This tool allows for a two-way data sharing between public agencies and mobility service providers, and enables cities to actively manage private mobility providers and the public right-of-way.

This type of digital infrastructure will be key in management of UAM operations as part of the total transportation system of the city. View

Recommendations:

- Incorporate UAM infrastructure into broader mobility infrastructure planning efforts, emphasizing the sustainability of UAM as a mobility solution.
    - » When designing mixed-use facilities for multiple modes of transport, or when integrating UAM into existing facilities, ensure UAM enhances functionality rather than diminishing, duplicating or dominating it.
    - » Develop tools to evaluate proposed multimodal solutions and ensure that they comply with existing safety requirements.
- Construct facilities sustainably, with locations and designs that maximize urban mobility, equity and safety.
- Anchor development in the UN Sustainable Development Goals (especially goal 9, related to resilient infrastructure) to ensure that new infrastructure enhances and prioritizes the lives of citizens while responsibly utilizing available resources (local, if possible).
- Consider energy generated and stored for vertiport operations as potential relay or buffer for surrounding communities, enabling smart, local and resilient grids.

Action Point 4: Develop regional planning guides for digital and energy infrastructure

By creating regional planning guides, stakeholders can empower urban planners to create bespoke solutions for their individual cities.

Recommendations:

- Include master guidelines for energy infrastructure.
    - » Share detailed results of energy impact studies.
    - » Incorporate lessons from city-level assessments.
    - » Consider involving utility companies in the early stages of planning.
    - » Support planners in creating scalable and sustainable solutions for their cities.
- Include master guidelines for digital infrastructure.
    - » Provide tools and resources to guide the development of digital mobility platforms.
    - » Provide guidance on data sharing and digital governance.
    - » Recommend that digital infrastructure planning be included in larger, city-level master planning work.
- Consider how UAM infrastructure could allow cities and regions to decentralize data and energy grids by incorporating data and energy infrastructure into mobility hubs as core components.
    - » Decentralizing grids can make overall networks more resilient to service outages and demand fluctuations, but doing so requires new policies to govern deployment, energy grid usage, and data security and privacy.

D) COORDINATING UAM INFRASTRUCTURE IMPLEMENTATION

Recognize the logistical and practical considerations in developing and implementing UAM infrastructure

Once the high-level goals for UAM infrastructure have been established, and the appropriate requirements and policy solutions put in place, stakeholders must proceed to the task of coordinating the real-world implementation. UAM infrastructure will inevitably bring with it numerous practical and logistical hurdles; stakeholders can begin working now to establish useful processes and address key issues. Top priorities in UAM implementation range from proposal evaluation processes and renewable energy solutions to operational safety compliance and data privacy. Action points include:

Action Point 1: Evaluate new transportation proposals using data shared through the region's digital platform and the private data market

Regions should use their digital mobility platform, as well as established data sharing practices and protocols, to better evaluate new transportation proposals as they arise.

Recommendations:

- Make use of digital infrastructure as it is developed to thoughtfully plan for and manage future mobility needs.
- Leverage digital mobility protocols (under the authority of a city or region), ecosystem usage data (e.g., auto and bicycle traffic data, energy grid input), and private data sets in urban mobility simulations.
    - » Note that, while transportation authorities have the right to oversee new proposals, they can also delegate this authority as they see fit.
- Allow transportation authorities to use the digital platform to make decisions about proposals for mobility projects:
    - » Each private or public entity could plug their respective models and algorithms into the reference city model, and run simulations to demonstrate the value and impact of their transportation services to the relevant authorities.
    - » Proposals vetted by the simulation should be given additional opportunities for evaluation, and should eventually be studied and validated through more detailed models.

Past & Ongoing efforts

Researchers worldwide have been since 2018 developing and using the open source Multi-Agent Transport Simulation Toolkit (MarSim). This tool could for example be used to model demand, traffic flow, routing issues, infrastructure placement, and for mobility providers to outline mobility scenarios, in order to help authorities intelligently plan and manage transportation.

A team from ETH Zurich, Technical University Munich and Bauhaus Luftfahrt has started modeling UAM integration into urban transport systems

View

Action Point 2: Engage and collaborate with local energy stakeholders to leverage renewable energy sources and strengthen the broader renewables market

Renewable and sustainable energy requirements are an ongoing priority for state and local authorities – as they should be for mobility providers – and UAM is well-suited to support efforts to increase usage of renewable energy in transportation systems.

Recommendations:

- Build support among local leaders for the design, funding, construction, operation and maintenance of a sustainable energy infrastructure to enable UAM.
- Align UAM energy infrastructure with the city's sustainability goals and carbon targets.
    - » Developing UAM hubs to serve both as components of a multimodal transportation network and as energy hubs in their own right can help to strengthen grid capacity and resilience.
    - » Electric propulsion in UAM vehicles brings inherent benefits, but must be paired with equally sustainable electricity generation – which itself is dependent on a region's specific sustainability goals – to realize its full potential.
- Build and maintain an ongoing dialogue to address evolving energy demands and municipal needs from energy providers.

Action Point 3: Address UAM operational safety compliance as a key stage in the infrastructure development and testing process

All operational components of UAM – including infrastructure – play an important role in achieving and maintaining safety compliance. Many guidelines for infrastructure and vehicle safety will come from the federal level in order to ensure consistency, while regional authorities will oversee certain aspects of infrastructure development and areas like noise level compliance.

- Ensure harmony in federal versus local policymaking.
- Involve regions in the process of determining UAM safety compliance for operational components (e.g., vehicles, airspace management), particularly for infrastructure development and operation.
- Build on existing guidance, such as FAA AC-150/5390-2C and ICAO Annex 14, Aerodromes, Vol. 2, to ensure that vertiports do not create additional safety and environmental risks for local residents. Monitor continuously to ensure compliance.
- Install sensors and data collection systems into vertiports to monitor UAM operations and to ensure compliance with local, regional and national safety and environmental standards, while also providing data to external services (e.g., weather).

Action Point 4: Create a robust privacy system for data collected by the digital mobility platform

Data collection and usage will be essential for ongoing operations, security and safety in any UAM system, and it is vital that stakeholders develop plans to ensure that data privacy is maintained for companies and users alike.

- Incorporate data-sharing from ride-hailing, micro-mobility and other mobility providers to accurately simulate and manage the transportation network, and to assess new mobility proposals.
- Use gathered data to monitor and enforce compliance with the rules and requirements of the mobility ecosystem.
- Address any privacy issues that may arise from the sharing of industry data with local transportation authorities:
    - The industry perspective: Ride-hailing companies have a vested interest in protecting proprietary and consumer data
    - The consumer perspective: Individual behavior and personal information may need to be both aggregated and de-identified to protect consumer privacy.
    - The security perspective: Law enforcement or security authorities may want access to industry data to protect against bad actors.

Conclusion

The process of integrating UAM infrastructure into cities will require ecosystem stakeholders to be thoughtful, inventive and, above all, collaborative. Much of the effort will require stakeholders to venture into uncharted territories, but in many respects, the path ahead is clear. To best serve citizens, UAM infrastructure must be implemented as a complement to existing transportation networks, rather than as a replacement or a competitor. In the end, implementation strategies will vary greatly by region and level of need, but as stakeholders work to advance the UAM cause over the next five years, the tools outlined in this chapter will help ensure that they are set on the right path.

CHAPTER 04

DESIGNING ROBUST SECURITY

SECURITY IN THE SKY AND ON THE GROUND:
A FOUNDATION FOR STRONG, FLEXIBLE PHYSICAL AND CYBERSECURITY SYSTEMS

CHAPTER SUMMARY

UAM presents an opportunity to expand the urban transportation landscape significantly, but operational realities pose a variety of potential security and privacy risks that may threaten those ambitions. These issues must be addressed by stakeholders in each of the five UAM functional domains – Vehicle, Operation Center, Vertiport, Traffic Management, and Business-to-Customer – while also being considered together under an overarching UAM Security domain. This chapter provides recommendations for designing high-level UAM security policies over the course of the next five years.

The five functional domains are all segments of the UAM ecosystem. The physical and cyber components of each segment will share a similar set of threats, security rules and regulations – no matter where they may be located. For example, all operations

centers are expected to face similar threats, with similar potential impacts, even though the centers themselves may differ considerably from one region to another. However, it is important that stakeholders also develop a holistic understanding of the entire UAM security chain.

To achieve this understanding, stakeholders must not only look at the five functional domains individually, but also consider them as a whole under an overarching UAM Security domain. This perspective will allow stakeholders to resolve security challenges that emerge in the gaps between the functional domains, and also ensure the consistency of security measures across domains. Creating a robust UAM security approach requires stakeholders to assess hazards comprehensively and reduce risks across the operation, including both physical and cyber threats. It also requires that stakeholders balance security requirements against potential impacts, both from a financial cost and passenger experience perspective.

In this chapter, we present recommendations for developing actionable policy solutions over the next five years to ensure cohesive security practices across the UAM ecosystem. Key areas of discussion include:

A) Bridge security chain gaps:	B) Map the risk environment:	C) Consult industry experience:	D) Enact new policies:
Resolve gaps in the UAM security chain to ensure all ecosystem components are protected by stakeholders with well-defined roles and responsibilities	Assess risks to develop a robust and resilient UAM security approach	Seek guidance for security policies from mature industries' best practices and determine suitability for UAM	Adapt and develop new security policies to protect against unauthorized activities during UAM operations.

A) BRIDGE SECURITY CHAIN GAP

Resolve gaps in the UAM security chain to ensure all ecosystem components are protected by stakeholders with well-defined roles and responsibilities

UAM covers five primary functional domains: Vehicle, Operation Center, Vertiport, Traffic Management and Business-to-Customer. While it's important to address security concerns for each of these areas individually, stakeholders must also take a broader perspective that considers the entire UAM operation – as well as any regional differences – in order to create robust, comprehensive security systems. This approach will facilitate the creation of baseline security requirements that can be used across regions and functional domains. It will also make it easier to assess security risks within individual functional domains. Action points include:

Action Point 1: Define and align the roles and responsibilities for stakeholders in each functional domain of the UAM security chain

Ecosystem stakeholders will need a holistic understanding of how various stakeholders should work together with regard to UAM security.

Recommendations:

- Create a UAM security map to help characterize the relationship between the five UAM functional domains, and identify any potential gaps in coverage.
- Ensure the map matches security roles and responsibilities to UAM stakeholders.

Action Point 2: Consider how regional or local requirements and regulations might impact security needs, priorities and measures

There will be no one-size-fits all approach for UAM security, so it is important to evaluate security needs within the context of the cities and regions where it is implemented.

Recommendations:

- Consult regional and local regulators, national security agencies, ATM controllers and telecommunications operators to identify local concerns, and tailor the security map as necessary to reflect these concerns.

- Be aware of regional and local cybersecurity laws and regulations related to topics such as critical infrastructure protection, data privacy and payment processing.
- Consider which threats are more serious or likely in a particular region.
- Assess whether particular threats create the same impact regardless of location.

Action Point 3: Issue baseline physical and digital security requirements for essential UAM systems

Establishing baseline security requirements will give ecosystem stakeholders a benchmark to work toward when building essential UAM systems.

Recommendations:

- Use the UAM security chain map to identify critical system nodes, i.e. UAM physical or informational assets having the highest value to stakeholders.
- --Characterize UAM security risks in terms of cyber, physical, or mixed security implications
- --Outline the relationship between critical system nodes and the broader UAM security chain
- Issue a baseline set of physical security requirements for vertiport operators and operation centers; local physical security risk should be assessed on a case-by-case basis.

On-Going Efforts

- The Munich Security Report articulates the current state of global security policy, major threats, and focus areas for international leaders to discuss, and could help support stakeholders resolving gaps in the UAM security chain. Link
- ICAO Universal Security Audit Programme (USAP) provides continuous auditing and monitoring the effectiveness of ICAO member States' aviation security implementation against international standards. This Programme is an example of how industry is working together to improve security effectiveness over time. Link
- Commissioned in 2019, the Blue Ribbon Task Force on UAS Mitigation at Airports could inform UAM stakeholder seeking to evaluate security gaps for UAM. The task force is studying the UAS incursion threat profile, effectiveness of current protocols, and providing recommendations for industry, regulators, and security agencies to collaborate on to mitigate and respond to the threat. Link

Action Point 4: Perform a preliminary assessment of security risks to the UAM functional domains

Ensure the consistency of risk assessments across functional domains by consolidating them into an overarching “UAM Security” domain.

Recommendations:

- Evaluate security risks related to traffic management and vehicle security (as identified in chapters 2 and 5). These include:
- Security concerns regarding use of unlicensed spectrum vs. use of licensed commercial and aviation safety spectrum
- Systems/procedures that will be needed to enable compliance with airspace rules (e.g., surveillance systems)
- Security of services that vehicles will use to share data with each other and with modernized traffic management systems
- Vehicle detection, vehicle identification and emergency response procedures
- Cybersecurity threats and monitoring procedures for ensuring external service providers’ system data security, resilience, and integrity (e.g., traffic management services, weather, booking)
- Determine whether high-level functional security risk analyses across systems will interfere with individual system safety processes and procedures.
- Identify any potential cybersecurity risks presented by the use of common software architectures for vehicle interoperability and ground stations.

B) MAP THE RISK ENVIRONMENT

Assess security risks to develop a robust and resilient UAM security approach

With the security chain mapped out and preliminary risk assessments complete, stakeholders should work to create a detailed map of the overall risk environment. This map will inform the development of UAM security policy, and help produce a strong and resilient UAM security approach. This assessment should include both digital and physical security risks, and should also cover related issues, such as liability concerns and secure communications between vehicles and the traffic management systems of the future. Crucially, security needs must be continually reassessed to ensure that new and emerging threats are addressed. Security will play a critical role in shaping the UAM ecosystem, impacting everything from the passenger experience to system-wide operational costs. These impacts must be considered from the outset of the policy development process, and balanced against the weight of potential security risks to ensure that security concerns do not hinder UAM adoption. Action points include:

Action Point 1: Identify vulnerabilities and risk factors for systems specifically

Stakeholders must pay special attention to cybersecurity needs, which will represent a major attack vector for bad actors operating against the UAM ecosystem.

Recommendations:

- Characterize the nature of possible cybersecurity threats (e.g., privacy breaches, malicious attacks or theft) and identify any potentially unsafe conditions (e.g., privacy violations, information loss, or loss of safety-critical information and software integrity).
- Assess each risk's potential impacts and rank them in order of severity to ensure standards development organizations and policymakers can prioritize risk reduction efforts effectively.
- **Action Point 2:** Create a risk profile for each physical node in the UAM security chain

UAM infrastructure will require robust physical security procedures to ensure the safety of citizens during UAM operations.

Recommendations:

- Build risk profiles and update them continuously to inform the development of appropriate risk mitigation strategies and procedures with security authorities
- Prioritize risk response according to the nature of the threat, how critical the system is and the extent of possible harm.

Action Point 3: Evaluate how to minimize passenger impact while still meeting system security requirements, in order to maintain positive passenger experience

To build a positive experience for UAM passengers, policymakers and vehicle operators must ensure that security procedures are effective without causing unnecessary inconvenience.

Recommendations:

- Evaluate all facets of the passenger security process; passenger experience can be highly dependent on security procedures both visible (e.g., biometric screening and boarding ID verification) and invisible to the public (e.g., background checks).
- Analyze passenger security from a multimodal perspective, including concepts like One ID for consistency across different types of transport.
- Explore supplementary funding models, such as:
  - National funding (e.g., trusts, direct funding)
  - Local or regional funding (e.g., taxes on services or operators)
  - Private funding (e.g., commercial system)
  - Hybrid funding (e.g., PPPs, privately operated public utility)
- Determine whether operators and user-based funding models can cover UAM's costs – either entirely or in part. If the costs are too high, how does that affect scalability and deployment across many cities with varying augmentation infrastructure?
- Outline the necessary oversight frameworks for various funding models.

Action Point 4: Assess costs of security implementation and operation across the UAM ecosystem

As UAM systems progress through development toward operational status, security systems will need to be continually updated and funded.

Recommendations:

- Incorporate security needs into UAM development roadmaps, both short- and long-term.
- Allocate security needs across the five UAM functional domains and assess costs for each domain.
- Evaluate funding and financing options for UAM security (particularly cybersecurity).

1. https://www.iata.org/whatwedo/passenger/Pages/one-id.aspx

Action Point 5: Assess any liability concerns arising from the UAM security chain, working with experts to refine roles and responsibilities as needed

Without a way of establishing and verifying responsibility for security events that occur during operation, few will be interested in participating in the new ecosystem, due to uncertainties around their potential liability.

Recommendations:

- Work with experts in the liability/insurance industry to refine responsibility models as needed.
- Rely on the security risk assessments and decisions on acceptability of residual risks to determine accountabilities
- Determine focal points for liability analysis in UAM, as these may differ from those seen in current commercial aviation models.

Action Point 6: Define and implement a procedure for periodic review of security risks

As circumstances surrounding UAM operations change over time, and as new potential threats emerge, security risks must be re-evaluated to ensure that safety is maintained.

Recommendations:

- Commit stakeholders in each domain to a periodic re-assessment of security risks.
- Perform regular reviews of the performance and cost of existing security measures across each functional domain, as well as for the overarching UAM Security domain, and make adjustments to security policies as needed. This task could be assigned to an independent third party such as ICAO's Secretariat Study Group on Cybersecurity (SSGC).

Action Point 7: Explore methods for securing communications between next-generation traffic management systems and vehicles

Although there is still much work to be done in developing UAM traffic management systems and vehicles, stakeholders should begin working now on developing strategies to secure communications between these essential ecosystem components.

Recommendations:

- Study the telecommunications industry, particularly current approaches to managing data link integrity fidelity and security, to inform requirements for communications protocols and technologies.
- Consider security concerns that will emerge from policy decisions on use of the aviation safety spectrum vs. use of the licensed commercial spectrum.

C) CONSULT INDUSTRY EXPERIENCE

Seek guidance for security policies from mature industries' best practices and determine suitability for UAM

Though UAM relies on many innovative new technologies, it also shares several similarities with existing industries like commercial aviation, air ambulances and autonomous vehicles. For this reason, stakeholders should explore security policies from these more mature industries and, where appropriate, use established best practices for guidance. The study of security policy development in these industries will also help stakeholders develop a more thorough understanding of the potential threats that UAM may face. Action points include:

Action Point 1: Identify lessons learned from previous policy development processes and post-incident responses

To ensure the UAM industry's long-term success, ecosystem stakeholders should aim to develop procedures for handling and investigating safety and security incidents.

Recommendations:

- Catalogue responses from analogous industries (e.g., autonomous vehicle failures, hacks, etc.) and characterize them based on threat type (e.g., malicious acts, negligence or acts of nature).
- Assess standard practices for post-incident investigation, such as those employed by civil or military investigative authorities.

Action Point 2: Identify best practices for framing legal responsibility for incidents like data breaches or accidents

Building on the liability assessment detailed in section B, UAM stakeholders can outline best practices for defining and refining models of legal responsibility.

Recommendations:

- Examine case studies from mature markets that are similar to UAM, such as air ambulance aviation and taxi services.
- Reach out to insurers who have already developed an approach to providing insurance for cybersecurity breaches, and learn from their methods.

- Develop an understanding of liability issues related to data breaches, accidents, malicious attacks, etc. when comparing UAM to commercial aviation and other industries.
- Consider how security issues for UAM compare to commercial aviation (e.g., in areas like access and communications) and other related industries.

On-Going Efforts

- The EU has developed the General Data Protection Regulation (GDPR) to protect consumer privacy and data use in the digital domains. The regulations provide requirements about disclosure when information is collected and how it will be used, empowering users to opt out if they so choose(https://eugdpr.org/)
- The Payment Card Industry Data Security Standard (PCI DSS) is an independently developed, industry standard for the processing of payments using debit, credit, and other digital cards for commercial transactions: https://www.pcicomplianceguide.org/faq/

Action Point 3: Examine emerging cybersecurity risks seen in mature industries

UAM stakeholders should look to other mature industries for best practices to mitigate cyber threats, and use policy development to reduce the risk of private data exposure and mitigate financial harms.

Recommendations:

- Study industries that experience frequent (and diverse) cybersecurity threats, such as:
  - » Information technology
  - » Traditional commercial aviation stakeholders
  - » Corporate finance
  - » Healthcare
- Consider how existing standards correspond to the UAM functional domains.
  - » Example 1: Payment Card Industry Data Security Standard (PCI DSS) for credit card transactions will be applicable for UAM customer payment
  - » Example 2: The EU's General Data Protection Regulation (GDPR) will apply to the collection, use and storage of consumer data in UAM

D) ENACT NEW POLICIES

Adapt and develop new security policies to protect against unauthorized activities during UAM operations.

Once risk factors have been assessed, policy impacts considered and industry best practices reviewed, stakeholders must begin implementing UAM security policies. These policies should include requirements and standards for general UAM risk reduction. Once policies have been enacted, it will also be important to establish a means of compliance for UAM security standards. Action points include:

Action Point 1: Develop requirements and standards for UAM risk reduction.

Maintaining enforceable standards for UAM security will help promote consistency and widespread adoption of essential security practices. However, these standards must be regularly reviewed to address changing operational circumstances, such as the emergence of new threats.

Recommendations:

- Ensure security in general data exchange and in the hand-off of authority between stakeholders during UAM operations.
- Require vehicle designers to incorporate security principles that are appropriate for vehicles and infrastructure, and which also align with any specific community needs.
- Maintain flexibility by periodically reevaluating security policies along several axes to keep track of the ongoing evolution of the threat environment.
- Engage in regular assessments to ensure that current policies are the most efficient and economically sustainable means of achieving desired security goals.
- Keep track of how existing threats – and the ecosystem's ability to address those threats – change over time.
- Identify new threats and determine whether current policies deal with them sufficiently.

Action Point 2: Develop requirements and standards for data management and data exchange across the ecosystem

UAM stakeholders must balance data flow and utilization while preserving customer privacy, system security and controlled access.

Recommendations:

- Consider the following elements of the data flow:
  - » Acquisition: Data flows from vehicles, customers, data service providers, etc.
  - » Usage: Data flows for route planning, ticket booking, examining threats, logistics planning, etc.
  - » Exchange: Data flows that determine how authority is exchanged between stakeholders during operations
  - » Storage: Data flows in dedicated storage facilities versus in active systems
  - » Distribution: Data flows routed through a dedicated infrastructure versus using non-secure communications

Action Point 3: Establish means of compliance for UAM security standards.

Creating standards through policies is only the first step in building a comprehensive security system; installation, enforcement and ongoing management are also necessary for practical compliance.

Recommendations:

- Streamline security systems development and implementation, where possible.
- Launch discussions with ICAO, International Air Transport Association (IATA), European Organization for Civil Aviation Equipment (EUROCAE) and US RTCA, European Aviation Safety Agency (EASA), and FAA regarding acceptable means of compliance based on existing standards for UAM.
- Align adjacent functional stakeholders on security strategies.

CHAPTER 05

DEVELOPING UAM VEHICLES

FROM PROTOTYPING TO SCALABLE TRANSPORT: BUILDING SAFE, RELIABLE AND SUSTAINABLE VEHICLES FOR UAM OPERATIONS

This chapter provides UAM stakeholders with an overview of key policy recommendations to further develop UAM vehicles over the next five years. Already, more than 200 companies have publicly announced their work on electric or hybrid-electric UAM vehicles, with efforts ranging from early concepts to functional, full-scale prototypes. These vehicles are rapidly approaching maturity, and their ongoing evolution has prompted important conversations about the policies needed to make UAM a reality.

Around the world, policy officials and private groups are working to address certification, eVTOL power standards, communications, navigation, emergency response and automation for UAM vehicles. However, much work remains, most notably with regard to testing in representative environments, certification and operational requirements. Today, the effort to develop safe, reliable and sustainable UAM vehicles is primarily driven by industry. However, it is vital that ecosystem stakeholders such as aviation authorities, policymakers and standards development organizations (SDOs) also work to support that endeavor.

These stakeholders can assist OEMs and suppliers by aligning on baseline technical requirements and supporting representative environment testing. Working together, these groups can ensure that regulations evolve alongside maturing vehicle technologies. This will enable technology developers to test in accordance with anticipated standards, further advancing UAM vehicle technology.

In this chapter, we outline recommendations regarding the policies that will be most critical over the next five years in helping vehicle engineers and designers prepare UAM vehicles for test programs and beyond. Key areas of focus for UAM stakeholders to consider include:

A) Establishing UAM Vehicle Interoperability:

Build consensus on guiding principles for vehicle development and operation

B) Pinpointing UAM Vehicle Regulatory Gaps:

Identify existing regulatory gaps in UAM vehicle development and certification

C) Developing UAM Vehicle Policy:

Address emerging technology challenges through policy development, where appropriate

D) Testing UAM Vehicles:

Test prototype UAM vehicle systems in increasingly realistic environments and in alignment with anticipated standards

A) ESTABLISHING UAM VEHICLE INTEROPERABILITY

Build consensus on guiding principles for vehicle development and operations

With hundreds of UAM vehicle concepts already in development, it is all but certain that there will be substantial differences between one vehicle and the next in terms of form, capability and functionality. Industry and regulatory stakeholders should spend the next five years working to align on the requirements, standards and guiding principles that will enable long-term interoperability to ensure a safe rollout in the early phases of UAM operations. At the same time, it will be important to align with communities on sustainability targets for UAM vehicles, and to begin establishing a flexible template for common vehicle operational procedures.

Action Point 1: Assess the landscape of UAM vehicle concepts for opportunities to align on interoperability

Achieving interoperability between vehicles, traffic management systems and other UAM actors will require building consensus among stakeholders all across the UAM ecosystem.

Recommendations:

- Map out the differences in operational vision across existing UAM vehicle design concepts and compare those against regulatory requirements.
- Reach consensus on a common language for UAM vehicle operations (e.g., mission types, vehicle functions, procedures).
- Establish guiding principles for interoperability between UAM vehicles, traffic management systems and operations in ATM airspace.
- Identify baseline characteristics for UAM vehicles that will enable shared vertiport use.
- Identify minimum standards and expectations for vehicle capabilities (e.g., safe operation, communication with one another, collecting and transmitting weather reports).
- Set minimum safety thresholds and targets for UAM vehicle design, with requirements growing more stringent as the vehicle progresses through each stage of representative testing and airworthiness certification.

Action Point 2: Align the industry on broad sustainability targets for UAM vehicles

UAM stakeholders have an opportunity to build a new form of mobility that promotes more sustainable energy usage, and sustainability should be prioritized at every step of the vehicle development process.

Recommendations:

- Identify energy sustainability targets for UAM vehicle design – such as vehicle lifecycle, energy source and emissions – in collaboration with vehicle and subsystem manufacturers.
- Identify opportunities to implement cleaner battery manufacturing processes.
- Consider ways to realize efficient use of urban power grid infrastructure for vehicle charging.

Action Point 3: Establish standards for common UAM vehicle operations

Building on the best practices of traditional aviation, regulators, security authorities, SDOs and OEMs should work to establish common procedures for UAM that will remain consistent across different types of vehicles and operators.

Recommendations:

- Ensure compatibility of essential systems across UAM vehicles (e.g., navigation, communications, data sharing, charging systems).
- Determine flight routes and collision avoidance strategies, noting that unmanned aircraft require a higher degree of navigation performance accuracy as compared to manned aircraft.
- Standardize procedures between general aviation systems and other UAM aircrafts.
- Establish procedures for safety and incident response.

B) IDENTIFY UAM VEHICLE REGULATORY GAPS

Determine existing regulatory gaps in UAM vehicle development and certification.

As industry stakeholders work to fill the technological gaps in UAM vehicle development, it is equally important that regulators identify the regulatory gaps that must be dealt with over the next five years before the vision of UAM can become reality. Vehicle regulations will help shape the trajectory of UAM vehicle development in the years to come, so it is important that they address the current regulatory gaps around vehicle communications, vehicle systems automation and vehicle electrification. It will also be crucial to establish regulations for pilot training, given that vehicle systems automation technologies are still very much in their infancy.

Action Point 1: Ensure reliable and secure communication between UAM vehicles and ecosystem actors

Reliable, secure communication plays an essential role in any form of aviation, and will therefore be an immediate and critical milestone for UAM.

Recommendations:

- Categorize technical and policy-related barriers appropriately so that ecosystem actors can easily understand the relationship between technological issues, and issues arising from gaps in regulatory requirements.
- Discuss the use of licensed and unlicensed spectrum for UAM communications, including questions of safety, reliability and availability.

Action Point 2: Explore regulatory paths for non-traditional, automated decision making in UAM vehicle systems

When it comes to UAM vehicles, automation is expected to play a key role in both the long-term business case of UAM and its overall safety and reliability; however, these benefits can only be realized if there is a path towards regulatory approval for automated systems.

Recommendations:

- Incorporate systems such as artificial intelligence and machine learning into UAM vehicle design.
- Implement incremental regulations corresponding to increasing levels of automation.
- Identify human involvement in decision-making at various levels of automation, and across

various phases in UAM vehicle development.

- Plan for future autonomy through different levels of integration for these systems:
- Detect and Avoid (DAA) systems
- Automated Mission Management (AMM) systems
- Vehicle Health Management (VHM) systems
- Human-Machine Interaction (HMI)
- Weather hazard geofencing, notification and avoidance systems
- Outline advantages and disadvantages of assigning safety-critical services in vehicles vs. traffic management systems (e.g., vehicle requirements for ADS-B and associated TIS-B/FIS-B systems, the need for a higher capacity system that precludes the use of ADS-B due to spectrum saturation).
- Illustrate how responsibility designation will affect certification for the overall UAM system (e.g., vehicle and traffic management).
- Include matters of UAM liability in the proposed ICAO UAM Working Paper for the 2022 Assembly.

Action Point 3: Assess remaining gaps in standards and practices for all-electric or hybrid UAM vehicles

Electric aircraft have already generated a great deal of attention from both technology and standards developers, however, there is still a need for consistent standards and requirements for all-electric and hybrid-electric vehicle design.

Recommendations:

- Ensure guiding principles are aligned when it comes to sustainable power use and compatibility with existing energy infrastructure.
- Capacity, reserve power and cycle life should be addressed in terms of fuel and power supply (e.g., distances traveled between refueling or power reserves that are considered acceptable to appropriate authorities).
- Unify and simplify proliferation of charging standards.
- Consider the implications of enabling interoperability across all vehicles and vertiports, such that any UAM vehicle can land and charge at any vertiport in the ecosystem, and the implications of declining to do so.

Action Point 4: Assess challenges in remote pilot training to achieve simplified UAM operations

Fully automated flights allowing UAM at scale are a long-term goal of most UAM flight service providers, and getting there will require new ways to handle piloting functions for vehicles and fleets, notably thanks to remote piloting. To reach that goal, it will be critical that policymakers and flight service providers begin establishing requirements to enable pilot training for UAM missions.

Recommendations:

Assess level of sophistication needed to make simulation training an adequate solution for training remote pilots of UAM vehicles.

- Facilitate future of more complex operations (e.g., one onboard operator per vehicle, one remote operator per vehicle, one remote operator per multiple vehicles, one remote operator per fleet).
- Resolve issues created by multiple service providers in one city, including high density traffic and interaction within ATM operations.
- Address deconfliction and integration with UAS traffic.

C) DEVELOPING UAM VEHICLE POLICY

Address emerging technology challenges through policy development, where appropriate

Technology and policy are tightly interrelated, and this is particularly true when it comes to UAM vehicle development. Indeed, many of the greatest challenges in this arena cannot be resolved by technical or regulatory solutions alone, and must be addressed via broader policy development efforts. Manufacturers must continue ongoing efforts to develop type certification processes and performance criteria for new UAM vehicle designs. As efforts to bring UAM to fruition accelerate, manufacturers will need waivers to test highly-automated vehicle systems in representative test environments, and common standards for vehicle charging, power, communications, navigation and surveillance systems. Policy will be a key enabler of technological advancement in these areas, so it is vital that UAM stakeholders work to address these challenges through proactive policy development wherever appropriate

Action Point 1: Create a type certification process for UAM vehicles anchored in performance-based compliance

As with all forms of aviation, any aircraft performing UAM operations must be certified both individually and as a "type" of aircraft. This certification establishes a vehicle's airworthiness, and is therefore an absolute requirement for commercial UAM operations.

Recommendations:

- Implement best practices from manned aviation for type and airworthiness certification related to vehicle mode of flight (e.g., multi-copter, tilt-wing/rotor, lift and cruise).
- Build on efforts by current working groups to establish a path towards vehicle airworthiness certification for eVTOLs (e.g., EASA's working group on UAM vehicle standards).

Past and Ongoing Efforts

Some notable efforts aiming to provide a frame for technology certification:

EASA issued in July 2019 the Special condition SC-VTOL-1, which is a complete set of dedicated technical specifications and airworthiness standards prescription, addressing the unique characteristics of VTOL aircrafts, for which there is currently no established type certification process. View

The Joint Authorities for Rulemaking of Unmanned Systems (JARUS) issued in September 2019 recommendations for Certification Specifications for Unmanned Aircraft Systems (CS-UAS), aiming to have a single set of technical, safety and operational requirements for all aspects linked to the safe operation of Unmanned Aircraft Systems. View

EASA issued in January 2020 the Special Condition SC-E 19 developed to provide certification requirements for Electric and/or Hybrid Propulsion System (EHPS) and support applications received by the Agency. View

Action Point 2: Establish a comprehensive policy framework to enable safe testing of UAM vehicles

UAM vehicles will need to undergo extensive testing before trial operations begin. This will require policymakers, industry stakeholders, research agencies and academic institutions to collaborate in establishing an overarching policy framework for that testing, covering everything from evaluation criteria to the waiver application process.

Recommendations:

- Establish a common framework for evaluating and testing highly-automated vehicle systems.
- Model the waiver application process on those used for other aircraft, taking into account the unique circumstances of UAM operations and performance.
- Focus on evaluating reliability, responsiveness, resiliency and intelligibility of machine decision making to better understand the logic behind it.
- Test in GPS or otherwise signal-denied environments.
- Create regulatory pathway for waivers using performance-based metrics.

Action Point 3: Develop common vehicle standards for UAM vehicle charging and power

Standards of interoperability and sustainability for vehicle charging and power systems will help to facilitate UAM's growth and long-term sustainability, and will also serve to ensure that UAM vehicles are able to operate safely in environments with limited UAM infrastructure.

Recommendations:

- Embed standards of sustainability and interoperability in the design process for vehicle charging and power systems.
- Investigate solutions that would enable stakeholders to develop a sustainable UAM ecosystem in which any UAM vehicle can land and charge at any vertiport with appropriate clearance.
- Encourage sustainable power generation and use for UAM.
- Investigate the feasibility of using and tracking battery swapping for UAM vehicles from both an economic and safety standpoint.

Action Point 4: Establish and refine communications, navigation and surveillance (CNS) system standards

To meet targets for early trial operations, OEMs must collaborate with policymakers, standards development organizations, ANSPs and subsystem suppliers to fully understand the baseline performance requirements they will need to meet, particularly for critical vehicle systems like CNS.

Recommendations:

- Address policy for CNS and weather sensing systems to define baseline navigation performance characteristics for UAM vehicles.
- Consider which existing standardized systems will need to be on board and how resilient, secure and effective these systems must be.
- Study the resolution and capacity of existing vehicle surveillance systems under UAM conditions:
- ADS-B for UAM vehicles
- Onboard detection systems (DAA system)
- Surveillance of cooperative and non-cooperative

D) TESTING UAM VEHICLES

Test prototype UAM vehicle systems in increasingly representative environments and in alignment with anticipated standards

We've already discussed the role that testing will play in the development of UAM traffic management systems (see Chapter 2, Section D), but it's important to explore the role of testing in UAM vehicle design as well. Testing is a crucial part of any vehicle systems development and certification effort, and is especially vital to UAM, given the high degree of safety and reliability required for operation in cities and surrounding regions. Vehicle developers need to work alongside policymakers and regulators to clearly define target objectives for the test programs as well as defining parameters of representative testing environments for UAM and a waiver process allowing safe testing.

Action Point 1: Outline the characteristics and parameters of representative environments for UAM vehicle testing

UAM operations and vehicle systems must be successfully tested in representative environments to ensure that they are ready for real world performance.

Recommendations:

- Define what constitutes a representative environment (e.g., population density, the required levels of safety).
- Investigate the possibility of simulated testing as a short-term approach for testing, and as a means for demonstrating UAM vehicle safety.

NASA and the FAA partnered to launch in August 2019 its UAM Grand Challenge, which will test the readiness of industry vehicles win a urban environment under a variety of weather and traffic conditions.
View

Action Point 1: Outline the characteristics and parameters of representative environments for UAM vehicle testing

UAM operations and vehicle systems must be successfully tested in representative environments to ensure that they are ready for real world performance.

Recommendations:

- Define what constitutes a representative environment (e.g., population density, the required levels of safety).
- Investigate the possibility of simulated testing as a short-term approach for testing, and as a means for demonstrating UAM vehicle safety.
- Establish critical baseline standards for acceptable levels of risk, which must be agreed upon by licensing authorities.
- Collaborate with industry, systems developers, CAAs, ICAO and SDOs on target objectives for simulation and testing programs.
- Model testing programs on similar efforts to test prototype autonomous vehicles in limited capacities.
- Outline traffic management concerns and needs for representative environment testing (e.g., infrastructure, safety).
- Outline the process for obtaining test waivers, exemptions or derogations.
- Effectively communicate this process to the industry.

Action Point 2: Work with industry and regional partners to facilitate development of testing areas and facilities

Vehicle manufacturers may collaborate with industry and regional partners to secure regulatory approval for representative environment testing, and to find space in which to perform this testing.

Reccomendations

- Investigate existing UAS test sites and corridors as potential locations for UAM systems testing, and study their approaches to Public-Private Partnership (PPP) to determine if any are applicable for UAM.
- Identify the shared funding and facility/support needs of industry vehicle manufacturers.
- Gain access to publicly-owned or supported test sites.
- Identify candidate locations that mimic a variety of real-world operational situations.
- Leverage underutilized helipads and community airports, which can likely serve as early sites for UAM operations, and as representative test environments for operations that will eventually be placed at larger airports.

Past & Ongoing Efforts

Notable companies making headway into certification.

In December 2019, Volocopter becomes the first eVTOL manufacturer to receive a Design Organization Approval (DOA) from EASA, a key step towards eventual certification.

In March 2020, and after the assessment of test flight plans and contingency plans, the CAA Norway CAA Norway issued an operational permit for EHang 216 to conduct flights together with a local customer for the purpose of testing and certification.

Action Point 3: Conduct safe testing of UAM vehicles in representative environments and facilitate meaningful UAM trial projects

Given the large number of aircraft that will likely be seeking certification in the near future, it is essential that regulators establish a process to provide waivers to UAM vehicle developers for testing their systems in representative environments. This will set the stage for the first UAM trial operations, which themselves will require additional coordination between regulators, local officials and industry stakeholders.

Recommendations:

- Align CAAs and systems developers on target objectives for programs that would test prototype UAM vehicles in limited capacities.
- Refine the regulatory pathway to enable permits and waivers allowing representative environment testing.
- Include appropriate safety fallbacks (e.g., backup driver in the car in the automotive industry).
- Align industry, regulators and local officials on a timeline for the first limited UAM trial operations.
- Frame authorization and letter of agreement (LOA) process with CAAs and/or ANSPs.
- Define necessary requirements for environmental, noise and visual pollution studies before commencing trial operations.

Conclusion

Though regulatory work has begun on vehicle development and UAM around the world, it's critical for stakeholders to continue to identify gaps in policy and devise a strategy for addressing them in a way that complements existing policies.