

# FLIGHT PLAN 2030

AN AIR TRAFFIC  
MANAGEMENT  
CONCEPT FOR URBAN  
AIR MOBILITY

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# FOREWORD

Over the last century, the birth of the aviation industry has fundamentally changed the way we live, work, and travel. With the advent of the urban air mobility (UAM) industry, aviation is once again taking a giant leap forward in making our dreams a reality. A new ecosystem, based on a new class of aircraft, will soon allow us all to traverse the urban skies with regularity. Changes in on-demand mobility, brought about with the ubiquity of smartphones and their accompanying mobile applications, mean that hailing a flight across town will be as simple as getting a taxi. Flying over our cities will no longer be the purview of the fortunate few. Air and ground transportation solutions will create a network of mobility that will enable people and goods to flow in a seamless, affordable way.

As we look toward the future, we know that smart, connected, and sustainable traffic management solutions will only arise through collaboration. Just as the automobile industry grew through the network of highways, so too will collaboration enable the UAM industry to grow through the creation of corridors, skyports, and information exchange networks. Technology will play a key role in the advancement of the UAM industry; we must prepare for change by testing and refining solutions before they are brought to market. We must also include community input in all of our decisions. Collaboration will be key to transforming this new and exciting industry from vision to reality.

Aviation never ceases to innovate. We dream of a future in which the gift of flight is available for all, and we look to the sky with anticipation. Join us in building the next chapter in aviation.

We would like to thank Dr. R. John Hansman (MIT), Jim Ullman (NATCA), Jim Eck (Harris) and all the professionals from Embraer SA, EmbraerX, Atech, and Harris who kindly contributed their expertise and feedback to the development of Flight Plan 2030 and the UATM concept.



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# EXECUTIVE SUMMARY

An exciting new chapter in aviation is unfolding. Innovations in aircraft design and advancements in technology will soon bring us electric vertical take-off and landing vehicles (eVTOLs, pronounced ee-vee-tols). These new aircraft will usher in the next generation of urban air mobility (UAM)—on-demand urban air services that carry passengers and cargo across a metropolitan area. UAM will revolutionize the urban mobility experience. Our daily commute will no longer be dictated by road and rail networks once eVTOLs enable us to go faster and with less effort. The next generation of UAM will be also more affordable than conventional helicopter transportation today. As a result, it has the potential to become a mainstream experience that will open new opportunities for communities and their economies.

For the UAM industry to grow to its full potential, we must prioritize community and industry engagement and start the planning process today. Flight Plan 2030 presents a concept for the design and management of low-altitude urban airspace that will allow UAM to evolve over the next decade. At that point, we anticipate advancements in autonomy will challenge our assumptions about air traffic management. We call our concept urban air traffic management (UATM).

Flight Plan 2030 describes a UATM solution that will enable the UAM industry to evolve to a future where eVTOL flights are a mainstream mode of transportation. We believe an urban

traffic management solution must provide shared situation awareness for all stakeholders, enable equitable airspace access, minimize risk, optimize airspace use, and provide flexible and adaptable airspace structures. UATM has two foundational services (Airspace and Procedure Design and Information Exchange) and four operational services (Flight Authorization, Flow Management, Dynamic Airspace Management, and Conformance Monitoring). Within this paper, we discuss each of these services in greater detail.

There are also many technologies that will enable the growth of this industry and support the UATM concept. We provide an overview of these technologies and discuss how their evolution over the next 10 years will enable the UAM industry to thrive.

Our solution prioritizes a procedures-based approach toward growing UAM operations while minimizing impacts on air traffic control (ATC). This concept has been developed with a close eye on community needs and the principles of human-centered design. UAM flights will affect neighborhoods, municipal transportation plans, infrastructure and commercial real estate investment, and more. It is critical that these voices are heard and that stakeholder concerns are taken into account at the outset. This white paper is a call to action for all of these stakeholders to come together and discuss what this exciting new reality will look like and how we will arrive there safely together.



PART 1:

# READY FOR TAKE-OFF



# A new generation of vertical take-off and landing vehicles will transform our urban mobility experience.

For millennia, the dream of flight has sparked our curiosity and fueled ingenuity. Generations of inventors have proposed ideas for ascending to the clouds, but it was not until the early 20th century that the first airplane successfully took off and powered flight became a reality. In the ensuing decades, the invention of the modern jet engine gave birth to a global aviation industry that brought unprecedented opportunity for human connection and commerce.

The next chapter in the story of flight is unfolding. Innovators are designing and testing a new generation of aircraft that will transport us across the cities of the 21st century. Advancements in avionics; electrical engineering; communication, navigation, and surveillance (CNS) technologies; autonomy; and artificial intelligence (AI) will enable us to revolutionize urban mobility.

Commuting in a large city can be frustrating and time consuming. Traffic jams, train cancellations, and roadworks often extend a short trip into one of a few hours or more. As we move into the future, urban populations will swell and put greater pressure on our existing transportation systems.

New possibilities are on the horizon. Our routes will no longer be dictated by road and rail networks because a new class of aircraft will enable us to go faster with less effort. Imagine a future where people access museums and visit businesses by flying across the city in minutes. Tourists take urban air vehicles to visit local destinations with ease, unlocking opportunities for economic growth. Commuters suddenly have a choice of routes because flexible transportation networks enable them to fly to major interchanges. Businesses deliver goods and services to customers more quickly and direct their resources more efficiently. In the air, piloted and autonomous aircraft, including drones, coexist safely and move expeditiously. These possibilities are just around the corner.

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## NEW AIRCRAFT WILL REVOLUTIONIZE URBAN MOBILITY

A new generation of aircraft, called electric vertical take-off and landing vehicles (eVTOLs, pronounced ee-vee-tols) will soon enable us to redefine the urban mobility experience. Although some eVTOLs may look similar to a helicopter, they will be powered by batteries, hybrid engines, or other new technologies that will make them much quieter than the helicopters of today. Advanced avionics will enable eVTOLs to navigate with high precision, exchange information digitally, and respond to changes in flight conditions autonomously. At initial launch, many eVTOLs will have pilots on board. With time, however, these aircraft will mature to a stage where they will operate autonomously.

The introduction of eVTOLs will challenge our assumptions about urban air mobility. Urban flights will become more affordable, in part, because eVTOLs will use less or no aviation fuel. With no runways required, passengers

and goods will depart from “skyports” or “vertiports” (i.e., areas with take-off and landing [TOL] pads) positioned at different locations across the city. From there, they will traverse over an urban area to another skyport in mere minutes. To date, more than 70 companies have already invested over US\$1B in the development of eVTOL concept vehicles (Booz Allen Hamilton, 2018). By 2035, forecasters estimate that 23,000 eVTOLs will be serving a global market worth US\$74B (Porsche Consulting, 2019).

At initial launch, many eVTOLs will have pilots on board. With time, however, these aircraft will mature to a stage where they will operate autonomously.



# URBAN AIR MOBILITY WILL UNLOCK NEW OPPORTUNITIES

With quieter and more affordable flights, eVTOLs will spur the growth of the urban air mobility (UAM) industry, a term that refers to on-demand urban air services that carry passengers and cargo across a metropolitan area. UAM is certainly not a new idea. Conventional helicopter operators have been providing intra-city transportation solutions for decades. Due to their cost and noise, however, the number of UAM flights in each city has been limited. Nevertheless, the recent convergence of several factors—including the rise of on-demand transportation, mobile technologies, more precise and reliable CNS technologies, and quieter aircraft—places UAM flights within reach of more people. Early predictions estimate that as many as 55,000 urban air taxi flights will eventually operate each day across the United States using 4,000 eVTOLs (Booz Allen Hamilton, 2018).

UAM infrastructure requirements and customer demands provide an opportunity to build new businesses and create new jobs. The development of skyports, or vertiports, across a wide metropolitan area will be critical to the growth of the UAM industry; the number and location of TOL pads will drive the number of UAM flights that a city can accommodate. Skyport operators will provide eVTOL fleets with battery swap or recharging services and deliver transit services to UAM passengers. Fleet operators will be responsible for managing fleets of eVTOLs that fly across cities. They will also interact with skyport operators and booking platforms that receive requests for passenger rides or cargo movements. If necessary, fleet operators will assign a pilot to operate a flight. These are but a few of the new opportunities that will be enabled by the growth of a UAM industry.



In some cities, the UAM industry is already growing. Commuters are using mobile devices to book on-demand rides on helicopters that serve as air taxis. Travel across the city takes minutes instead of the usual hour or two.

The UAM industry will expand quickly as the availability of eVTOLs grows. Communities will benefit from new economic opportunities as businesses and customers connect more seamlessly across large metropolitan areas. Cities will be able to bolster multi-modal transit systems and create greater flexibility in transportation networks. Health service providers will be able to

access regional communities more quickly. This in turn will maximize their time with patients, who will be able to access care more quickly. Ubiquitous urban flights will no longer be the domain of science fiction.

**Early predictions estimate that as many as 55,000 urban air taxi flights will eventually operate each day across the United States using 4,000 eVTOLs.**

## FLIGHT PLAN 2030: A ROADMAP FOR THE NEXT 10 YEARS

The next decade will be critical to the growth and acceptance of the UAM industry. During this period, standards for safety, security, and performance will be defined. Communication and data exchange standards will be created, and frameworks for airspace design and management will be decided. Technological advancements will push eVTOLs closer to full autonomy. The decisions made in the next decade will determine how and if UAM will be implemented in different cities and countries.

The UAM industry has the potential to deliver economic opportunities and urban mobility solutions that benefit communities. Realizing these benefits, however, requires workable solutions that ensure safe airspace coexistence, as well as community acceptance. Finding the right solutions requires collaboration and planning.

However, there is a danger that the industry will falter due to an inability to grasp the scope of future challenges and complexities. Communities will want assurances that noise from urban flights is acceptable (Vascik and Hansman, 2017b). Regulators and air navigation service providers (ANSPs) will require that flights remain safe, orderly, and efficient, while minimizing impact on airline and air traffic management (ATM) traffic (International Civil Aviation Organization [ICAO], 2016). Operators of small drones will want access to low-altitude airspace, while fleet operators will need equitable access to urban corridors. General aviation (GA) pilots of fixed-wing aircraft and helicopters will want to fly above urban areas with the freedom they enjoy currently. The urban airspace needs to accommodate the needs of all these stakeholders. Flight Plan 2030 does



not address all of the challenges facing the UAM industry. However, it does address one of the most critical: the design and management of the low-altitude urban airspace.

The next decade will be critical to the growth and acceptance of the UAM industry. It is during this period that standards for safety, security, and performance will be defined.

Collaboration and planning must start today. We need to find traffic management solutions that enable interdependent technologies and procedures to work harmoniously. Community and industry engagement needs to commence now so that the systems and infrastructure that enable UAM will be acceptable to all stakeholders. As UAM flights begin, we need to collect data that will inform decisions affecting how UAM may grow to its full potential.

Flight Plan 2030 presents a vision that will enable the UAM industry to transform from a concept to a reality. By testing new concepts, we can gain insights that will grow the UAM industry safely and fully realize its benefits. Beyond 2030, shifts toward air and ground autonomy will usher in a new era that will challenge our assumptions about traffic management.



## UAM CHALLENGES ATM SYSTEMS

As more eVTOLs become available, the needs of the UAM industry will challenge ATM systems. Once this industry grows to maturity, UAM flights will increase pressure on urban airspace capacity with the potential to overwhelm current ATM infrastructure, procedures, and resources.

Today, ANSPs provide ATM services for aircraft in all stages of flight from gate to gate. This includes services in the surface and terminal environment (i.e., the airport and its surrounding airspace), as well as the en route environment (i.e., high-altitude airspace). ATM is designed to manage flights between cities. Communications are primarily via radio, and surveillance technologies track aircraft that are spaced miles apart. Ground-based navigational aids serve as a backup to Global Navigation Satellite System (GNSS) surveillance information, but these are not suitable for surveilling UAM traffic. Current CNS technologies, airspace structures, and procedures over low-altitude urban areas are designed for helicopters and GA aircraft that self-separate using see-and-avoid procedures.

UAM flights have unique needs. They will take off and land from numerous skyports across a city. They will require smaller separation standards than those today to accommodate the anticipated high traffic volumes. They will carry passengers and goods, fly in closer proximity

to buildings and other aircraft, rely more on data link rather than voice communications as eVTOLs transition to autonomy, and operate in airspace adjacent to fixed-wing commercial aircraft. UAM flights will also spend most, if not all, of the duration of flights over densely populated areas, as they share airspace with traditional urban traffic such as helicopters and fixed-wing aircraft. These are only some of the many differences.

Going forward, traditional demands on the ATM system are expected to grow in parallel with growth in the UAM industry. Forecasters estimate that the global volume of air traffic is expected to double to 7.8 billion flights a year by 2036 (International Air Transport Association [IATA], 2017), a significant rise that will undoubtedly exert pressure on existing ATM resources, including the air traffic control (ATC) workforce.

Once this industry grows to maturity, UAM flights will increase pressure on urban airspace capacity with the potential to overwhelm current ATM infrastructure, procedures, and resources.



## UAM CHALLENGES THE UTM FRAMEWORK

Another traffic management system being developed today is unmanned aircraft system (UAS) traffic management (UTM) (Federal Aviation Administration, 2018; Kopardekar et al., 2016). UTM is a system for small UAS (sUAS), or drone, operators and stakeholders to interact, share information, and maintain safe separation. It is still under development, and opinions vary regarding appropriate roles, responsibilities, and regulations. Today, researchers and policy makers are refining the UTM framework to meet the needs of each country and region. To support shared situation awareness and decision making, sUAS operators use a decentralized information network that connects with UAS service suppliers (USSs) and ATM through a Flight Information Management System (FIMS) (Rios et al, 2017).

While UTM holds much potential for drone operations, gaps exist in its suitability for UAM flights. The initial launch of eVTOLs will include piloted aircraft that use voice communications—a mode of communication that is not supported by UTM. There is also no authority that controls or maintains situation awareness of all sUAS operations in a given area, which makes this framework unsuitable

for executing an integrated flow management plan. When unexpected changes or emergencies arise, the UTM system will not be able to provide a responsive service with a human operator who can make timely, informed decisions. UTM is explicitly designed to support sUAS operations—not mixed-equipage traffic over a large urban airspace where some pilots rely on radio communications and aircraft carry people from one skyport to another.

**Given the ongoing development of technology and regulations, we do not believe that for the foreseeable future, UTM will be suitable for managing UAM flights.**

Given the ongoing development of technology and regulations, we do not believe that, for the foreseeable future, UTM will be suitable for managing UAM flights. UTM has much potential, but it is still a framework designed explicitly for unmanned aircraft and small drones in particular.







## URBAN AIR TRAFFIC MANAGEMENT ENABLES UAM GROWTH

We propose a new approach called urban air traffic management (UATM). UATM is a system that will use strategically designed airspace structures and procedures to ensure urban flights remain safe and efficient while minimizing the impact on ATM. These structures and procedures will be enabled by technologies that include but are not exclusive to CNS, autonomy, AI, and information exchange networks. As technology evolves, it will drive change in the possibilities for UATM. We are sure that technological capabilities in the future will be impressive, but their role will be to enable new airspace designs and procedures so that the UATM system remains agile, responsive, and harmonized.

Each UATM implementation will need to be tailored to the needs of the urban area it serves. Community engagement will be particularly critical, as concerns about noise and privacy can have a significant impact on the acceptability of UATM operations. Input from the GA community, skyport operators, and fleet operators will inform decisions that may affect equitability in airspace access and the position of routes. Emergency

procedures will need to be designed in collaboration with skyport operators so that an adequate number of emergency TOL pads are available along UATM routes. Skyport operators will also need to adhere to minimum operational performance standards, as will all participants in the UATM airspace. We do not envision that skyports will be controlled, as is the case with fixed-wing traffic in approach airspace. Subsequently, close collaboration with UAM stakeholders will be critical to ensuring flight safety from departure to landing.

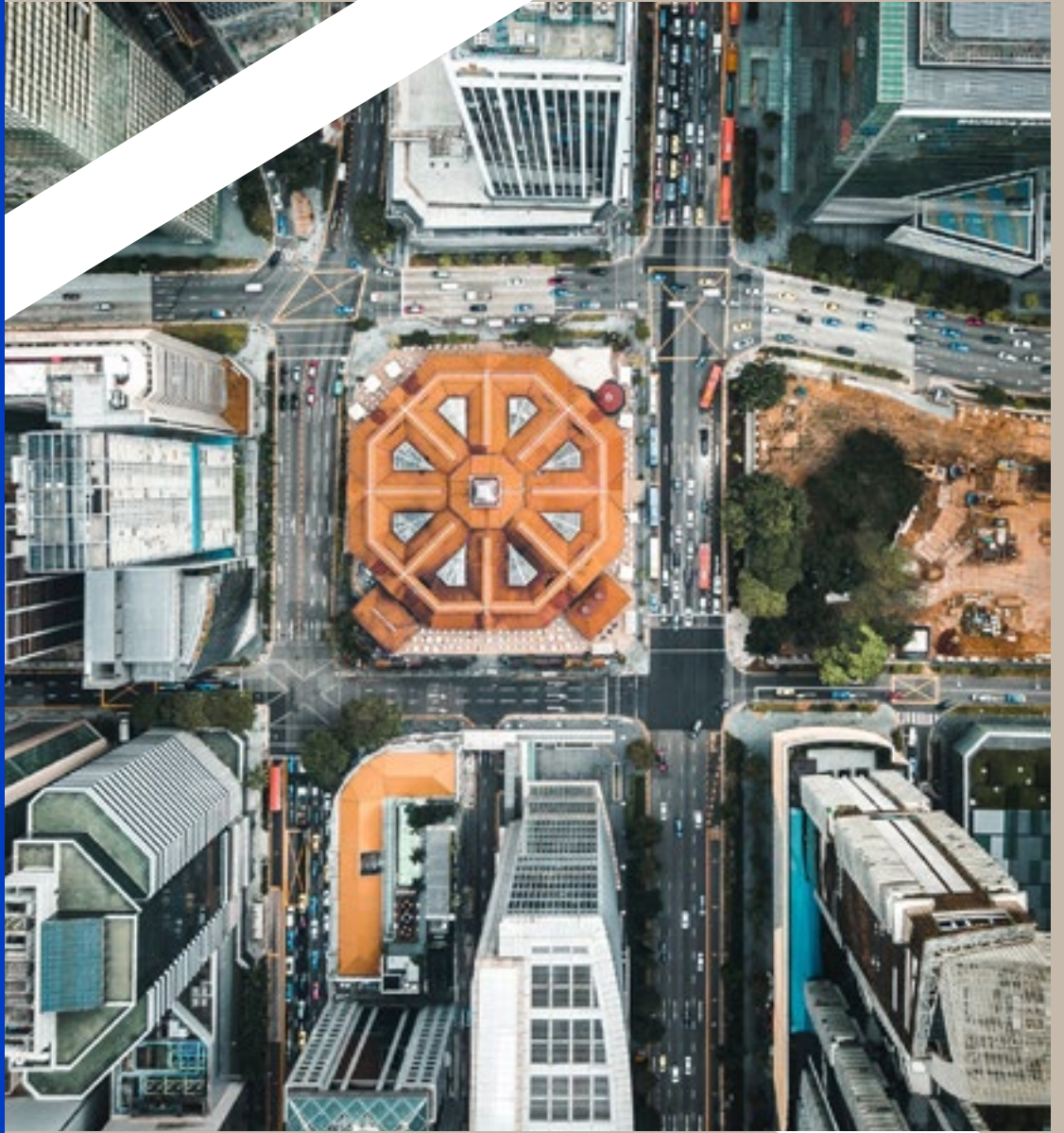
We propose a new approach called urban air traffic management (UATM). UATM is a system that will use strategically designed airspace structures and procedures to ensure urban flights remain safe and efficient while minimizing the impact on ATM.



The UATM airspace will be positioned between sUAS operations and ATM-controlled airspace. This layered approach enables the ANSP to increase urban airspace capacity and provide equitable airspace access for new and legacy aircraft. Moreover, UATM provides a structured traffic management system with a single airspace authority. It is explicitly designed to organize traffic flows,

mitigate risks in the air and on the ground, and support safety-critical situations when needed. As the UATM system evolves, it may eventually integrate all UAS operations so that all low-altitude aircraft—piloted and autonomous—operate within a single system. However, for now, we anticipate the UATM system will only manage traffic that primarily flies above sUAS operations.

*Welcome to Flightplan 2030.*



PART 2:

# ABOVE THE CITY

## UATM integrates mixed-equipage flights across urban skies.

Driving across the urban landscape requires navigating streets, stop signs, signal lights, and crosswalks. Traveling on roads and highways requires us to observe different speed limits. Signs alert us to turns, upcoming exits, and hazards while lights meter traffic flow. These road structures provide boundaries while the rules create a shared understanding of how we can expect others to behave. These structures and procedures keep everybody separated and moving. But more importantly, they mitigate risks not just for cars but also for pedestrians and bicyclists who share urban roads.

Similarly, the urban airspace of the future will be structured with routes, corridors, and boundaries that will define where UAM aircraft may fly. These structures will provide predictability to traffic flows while procedures will ensure that all stakeholders have a consistent understanding of operating rules. Moreover, the UATM system will keep traffic flowing, provide predictability, and mitigate safety risks.

The UATM system will be procedures-based first and foremost. While technologies such as CNS, AI, and automation will be critical in enabling the UATM system, procedures and airspace structures will remain the foundation of airspace management.

The UATM system will be procedures-based first and foremost. While technologies such as CNS, AI, and automation will be critical in enabling the UATM system, procedures and airspace structures will remain the foundation of airspace management. As technology evolves, it will drive change in the possibilities for UATM procedures and urban transportation.



# AN URBAN AIRSPACE SERVICE PROVIDER WILL MANAGE URBAN TRAFFIC

We envision that a single entity, an urban airspace service provider (UASP), will be responsible for managing low-altitude urban air traffic. In close collaboration with ATM, USSs, and UATM stakeholders, the UASP will deliver a suite of services. It will also manage traffic in the cruise phase of flight as aircraft operate between skyports. However, unlike ATM operations, the UASP will not control traffic movements on or above skyports.

As the single authority for managing the urban airspace on a daily basis, the UASP will have authority to open and close routes, grant flight authorizations, and execute a single, integrated flow management plan. The UASP will collect, analyze, and exchange airspace and flight information to support safe operations. When an emergency or off-nominal situation arises during flight, the UASP will have human operators who will communicate with pilots and fleet operators to guide aircraft to safety.

**We envision that a single entity, an urban airspace service provider (UASP), will be responsible for managing low-altitude urban air traffic.**

Each city and/or country will have a different approach for creating a UASP depending on the ANSP, regulations, policies, strategies, and resources. Some countries may decide that the ANSP should extend its current role and manage the low-altitude urban airspace. Other countries or states may decide to assign UASP responsibility for each city to a third party. Implementation will inevitably

differ between countries, and allocation of authority to a UASP will vary across a spectrum. Nonetheless, a central authority is needed for managing the UATM airspace of each urban area and ensuring that traffic flows safely and efficiently using a single flow management plan.

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## UATM DESIGN PRINCIPLES

*UATM services must be designed with a set of core principles. These principles are a north star that ensure UATM remains acceptable, safe, and equitable as the scope and nature of the services evolve.*

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### PROVIDE SHARED SITUATION AWARENESS FOR ALL STAKEHOLDERS.

Provide all stakeholders with access to the same accurate and timely information so they can make informed decisions to maintain operational safety.

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### MAINTAIN EQUITABLE AIRSPACE ACCESS FOR ALL STAKEHOLDERS.

Allow appropriately equipped and registered aircraft to have equitable access to the UATM airspace.

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### MINIMIZE RISK TO OPERATIONAL SAFETY.

Minimize or mitigate risks to operational safety by ensuring that UATM safety performance meets or exceeds that of the current urban airspace operations.

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### OPTIMIZE AIRSPACE USE.

Design capacity into the urban airspace system by using strategically positioned airspace structures and applying traffic management procedures.

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### ENSURE AIRSPACE STRUCTURES ARE FLEXIBLE AND ADAPTABLE.

Develop airspace structures, such as boundaries, routes, and corridors, that can be activated, deactivated, or moved in response to traffic demands, weather conditions, and other changes in conditions.

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# UATM SERVICES ENABLE THE UAM INDUSTRY TO GROW SAFELY

We believe the following six services will be the cornerstones for building a robust and resilient UATM system. They can be divided into two foundational services (those that prepare the airspace for UAM operations) and four operational services (those services necessary for ongoing, daily

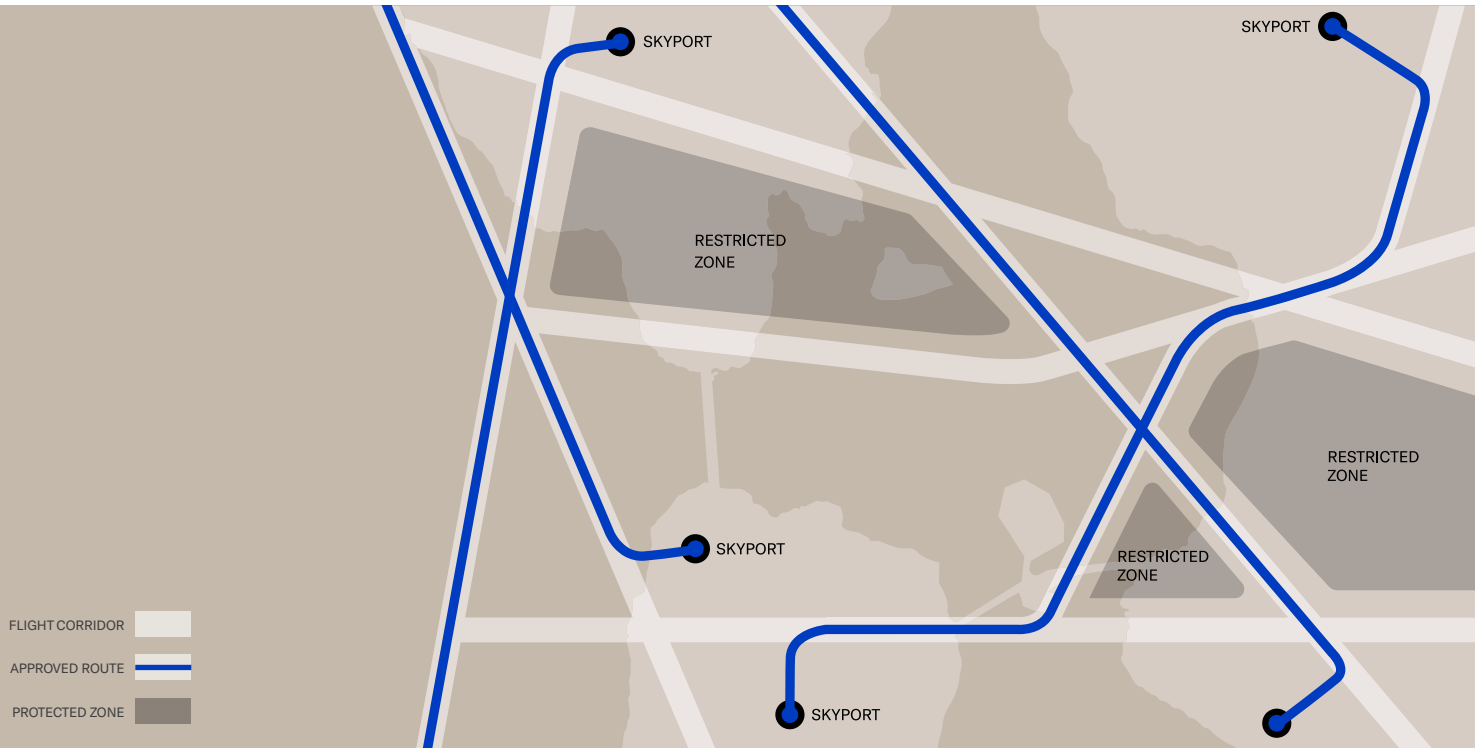
UAM operations). Because each airspace is under the authority of distinct laws, regulations, and an ANSP, details for roles and responsibilities will ultimately be decided upon on a jurisdiction-by-jurisdiction basis. Table 1 describes each service and its role in supporting the UATM system.

	UATM SERVICE	DESCRIPTION
<b>FOUNDATIONAL SERVICES</b> Services that must be established before UAM operations begin	<b>AIRSPACE AND PROCEDURE DESIGN</b> Creating urban airspace routes, corridors, and procedures	Pre-planning routes, corridors, airspace boundaries, and procedures for safety and environmental concerns, while maximizing use of airspace to enable the UAM industry to thrive
	<b>INFORMATION EXCHANGE</b> Exchanging airspace and flight information with all stakeholders	Sharing information with all stakeholders in UATM and adjacent airspace management systems, such as ATM and UTM; providing critical information to enable operational services
<b>OPERATIONAL SERVICES</b> Services that are delivered on a daily basis to manage airspace and flights	<b>FLIGHT AUTHORIZATION</b> Authorizing registered aircraft and pilots for flight in UATM airspace	Receiving flight requests, identifying optimal routes, and assigning 4-D flight requirements before authorizing a flight for UATM operations
	<b>FLOW MANAGEMENT</b> Spacing aircraft to maintain the integrity of the UATM operation	Managing the volume of traffic and assigning metering times to ensure safe spacing of aircraft
	<b>DYNAMIC AIRSPACE MANAGEMENT</b> Managing routes, corridors, and airspace boundaries dynamically	Shifting pre-planned routes, corridors, and geofenced areas when flight restrictions are activated; moving, opening, and closing routes in response to flow management needs, ATM needs, and changing weather conditions
	<b>CONFORMANCE MONITORING</b> Ensuring flights conform to flight and assisting pilots during off-nominal situations	Monitoring all traffic to maintain safety and provide guidance for any deviations; giving emergency aircraft immediate assistance and activating airspace and traffic flow adjustments to keep flights safe

TABLE 1. SIX SERVICES FORM THE CORNERSTONES FOR UATM

# AIRSPACE AND PROCEDURE DESIGN

## CREATING URBAN AIRSPACE ROUTES, CORRIDORS, AND PROCEDURES



**Routes:** Linear pathways defined by Global Positioning System (GPS) waypoints that accommodate a single vehicle laterally and vertically

**Corridors:** Transit pathways with a defined width and height that accommodate numerous vehicles separated laterally and/or vertically—akin to highways with lanes

Airspace structures (i.e., routes, corridors, and boundaries) and procedures will enable existing traffic—such as fixed-wing aircraft

and sUAS—to coexist safely with eVTOLs while maximizing the capacity of urban airspace. Airspace structures will include airspace boundaries, routes, and corridors that feature metering and transition points. In addition to defining where aircraft will fly, the structures will identify points in space where aircraft will enter or exit adjacent airspace (e.g., controlled airspace near airports). These predefined points in space will provide predictability and support shared situation awareness for ATM and sUAS operators.

Structures and procedures will be especially important for organizing traffic in the UATM airspace, where the diversity of aircraft equipment will increase and the volume of urban air traffic will grow. Airspace design and the positioning of routes will be of particular interest to communities given

the potential for noise. As such, the design process will include engagement with communities and industry.

Given the complex mix of aircraft equipage, airspace structures will be critical for organizing traffic and managing flows efficiently. Different rules and constraints will apply to different airspace structures. Access to some corridors may be restricted, and lower-altitude airspace may be reserved for drones. High-capacity corridors may require aircraft and crew to be appropriately equipped and certified, similar to performance-based navigation (PBN) routes.

UATM procedures will define how UAM flights will communicate, operate, and interact with the UASP and other

stakeholders. Within these procedures, contingency plans will define stakeholders' roles and responsibilities during off-nominal situations and emergencies.

Although initially, eVTOLs will have little impact on urban airspace, well-designed airspace structures and procedures will be critical to mitigating risks, maintaining efficient traffic flow, and retaining community acceptance of the UAM industry when traffic reaches high volumes. Defined routes and corridors will be important tools for strategic deconfliction. Procedures will ensure that all stakeholders, including ATM, sUAS operators, skyport operators, and fleet operators, interact safely and share consistent situation awareness.

## INFORMATION EXCHANGE

### EXCHANGING AIRSPACE AND FLIGHT INFORMATION WITH ALL STAKEHOLDERS

Information empowers people to make informed decisions. When all stakeholders can access timely, consistent, and accurate information, they can collaborate confidently and make decisions quickly. An information exchange will be a critical service that enables all stakeholders—within and beyond UATM—to interact, share information, and make decisions using a consistent set of data.

The UATM airspace will be a dynamic place where the status of skyports, corridors and routes will change rapidly. To this end, an information exchange is a foundational UATM service. The information exchange will derive data from numerous sources, such as aircraft sensors, weather sensors, skyports, pilots, ATM systems, and USSs. These sources will provide stakeholders with numerous types of information, including a database of aircraft and pilots certified for UATM operations or operations in restricted corridors, the



density of traffic flows, statuses of routes and corridors, and the availability of TOL pads. Real-time data regarding weather in the low-altitude airspace will be particularly critical. The information exchange will also serve as a portal for interactions with ATM and UTM stakeholders.

**The information exchange will derive data from numerous sources, such as aircraft sensors, weather sensors, skyports, pilots, ATM systems, and USSs.**

A robust and resilient information system that integrates modern networking architecture will be needed. The information exchange will also interface with ATM information systems, such as the System Wide Information Management (SWIM) system. Given that

data will be exchanged across numerous systems, the format will need to be standardized and consistent with ICAO plans. The exchange will also require robust approaches for ensuring that data are protected by a cyber-resilient network developed as a part of the UASP's cybersecurity strategy.

As UATM and the information exchange system evolves, new opportunities will arise, some of which may extend beyond urban airspace operations. Smart cities of the future may leverage the information exchange. Communities may wish to integrate data from the information exchange to inform decisions about city transit services. These data may aid cities in dynamically allocating resources to current and forecasted conditions. Data from the information exchange may also inform cities' data analytics efforts as city planners identify patterns and trends in transit and passenger throughput given certain weather conditions, time of year, or other notable events.

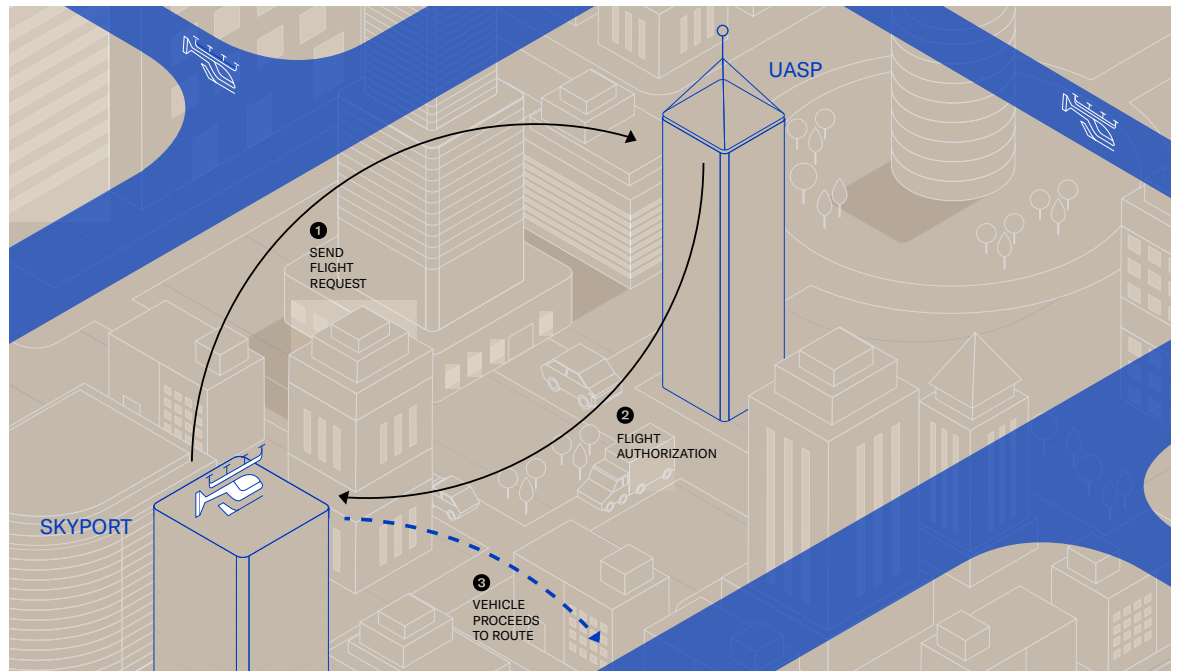
## FLIGHT AUTHORIZATION

### AUTHORIZING REGISTERED AIRCRAFT AND PILOTS FOR FLIGHT IN UATM AIRSPACE

Flight authorizations will provide fleet operators and pilots with a clearance to fly in UATM airspace. It will include an assigned route and, if necessary, a 4-D metering requirement. The flight authorizations are a critical service that will support the UASP in strategic planning, conflict avoidance, and flow management. The flight authorization will enable fleet operators and pilots to be confident that the flight is strategically deconflicted and that the requested routes, corridors, and airspace will be available at departure.

**The flight authorization will include departure time, 4-D requirements for metering points in routes and/or corridors, and a slot time for arrival.**

The authorization process will begin when stakeholders register with the UATM system. Fleet operators will register pilot and aircraft



information, thereby complying with identification, equipment, and certification requirements. Similarly, skyport operators will register their skyport capabilities and provide real-time data about TOL pad availability through the information exchange. These preloaded data will become the foundation for real-time flight authorization after a flight request is submitted.

Automation and interactions with the information exchange system will enable fleet operators and pilots to obtain a flight authorization minutes after receiving a request. To obtain a flight authorization, a fleet operator will submit a flight request to the UASP using the information exchange system. It will contain basic details such as departure point, destination, requested time of departure, and (optionally) routes and corridors. However, it will not need to specify a flight path, because the UASP automation will identify the optimal route. When the flight path is the mission profile, such as with tourist flights, a specific route or corridor may be requested. The UASP will then receive the flight request. The automation will check for the aircraft and pilot's certification level and then identify optimal routes. Once the flight authorization is approved, it will be sent to the fleet operator and the pilot. The

flight authorization will include departure time, 4-D requirements for metering points in routes and/or corridors, and a slot time for arrival. The pilot will then accept or reject the flight authorization.

Given that an authorization will contain an assigned departure time and 4-D requirements, it will be the responsibility of the fleet operator and pilot to ensure that passengers or cargo are ready by that time. If a delay occurs, the fleet operator will need to submit a request for a new authorization. In cases where the flight request cannot be met, alternative options will be offered so that operators receive flight authorizations in a collaborative and dynamic manner.

The flight authorization process will enable the UASP to anticipate traffic demands and strategically adjust routes and/or corridors to meet that demand. The receipt of flight requests also enables the UASP to monitor airspace demand in real time, collate data on traffic demand patterns, systematically improve flows by adjusting the airspace structure, and respond proactively with any needed adjustments to the strategic flow management plan. Moreover, a flight authorization service helps ensure that the UATM airspace is managed with a single strategic flow plan.



## FLOW MANAGEMENT

### SPACING AIRCRAFT TO MAINTAIN THE INTEGRITY OF UATM OPERATIONS



Commuters will fly over road congestion as a result of UATM flow management services that will keep UAM traffic moving. The primary goal of flow management is to optimize airspace capacity safely and minimize congestion while traffic demand fluctuates over the course of the day.

Technologies such as predictive analysis tools and time-based metering models will be critical for monitoring traffic flows and responding to changing airspace demands. Time-based metering will be used to regulate traffic flows and strategically deconflict aircraft along routes and corridors from departure to arrival. When airspace structures, such as corridors and airspace boundaries, need to shift with demand or other conditions, the flow managers who monitor automated flow management tools will respond accordingly.

Flow management will also be tightly coupled with the flight authorization process. Automation will monitor congestion and capacity along routes and corridors so that the flight authorization process supplies a steady stream of aircraft to optimize airspace use. Flow managers will determine the optimal departure release times, landing times, and slots in the routes and corridors by using 4-D trajectory models. Traffic patterns will also determine when and how airspace structures are adjusted to respond to demand. Strategic flow management activities will include opening, closing, and moving routes or corridors as needed to respond to demand, flight conditions, and stakeholders' needs.

**Automation will monitor the progress of flights once airborne to ensure metering times are met and safe spacing is maintained.**

Automation will monitor the progress of flights once airborne to ensure metering times are met and safe spacing is maintained. Metering times, especially departure and arrival times, for each aircraft will adjust dynamically in response to real-time data

from factors such as weather, skyport status, passenger demands, and off-nominal situations. It is through the oversight of flow management that conflicts, compliance with 4-D requirements, and dynamic airspace changes are recognized and addressed.

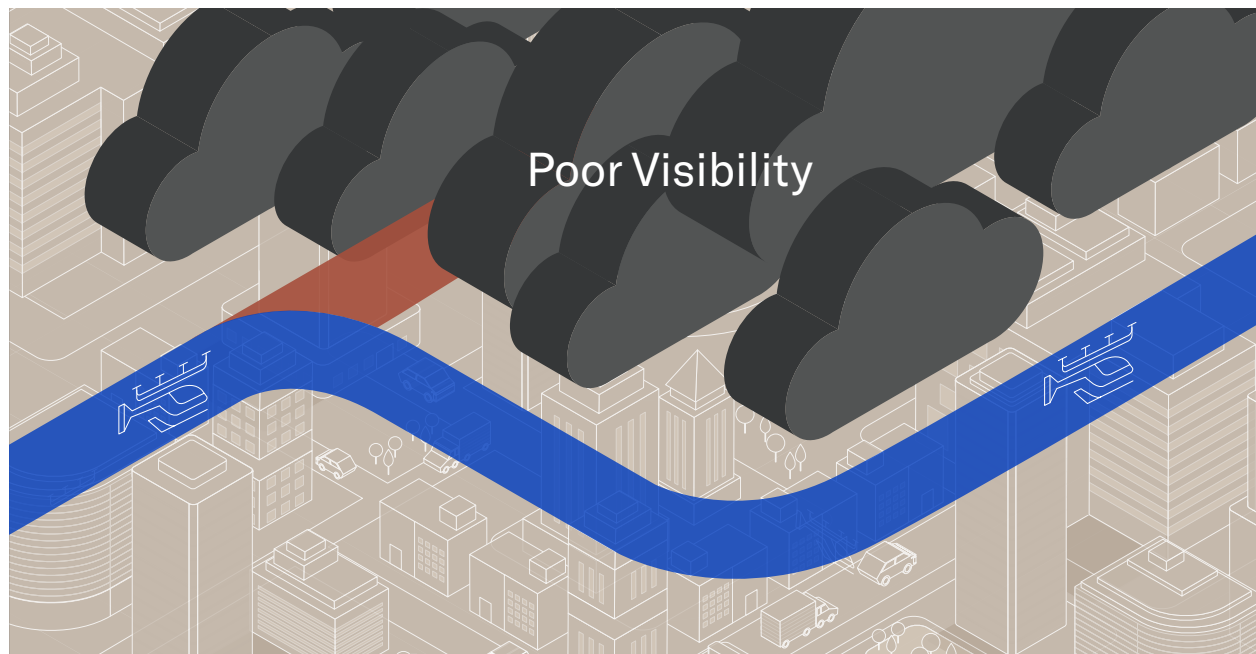
## DYNAMIC AIRSPACE MANAGEMENT

### MANAGING ROUTES, CORRIDORS, AND AIRSPACE DYNAMICALLY

Similar to ATM, operations in UATM airspace will be dynamic. These constant changes demand that the UASP be responsive and the airspace structures be flexible. Accordingly, dynamic airspace management will be a core service that enables continuous and flexible UATM operations.

The UASP will have a pre-defined set of airspace structures that are strategically positioned to support the dynamic needs of UATM stakeholders. During the course of daily operations, the UASP will open, close,

and move routes, corridors, and airspace in response to traffic demands, weather conditions, emergencies, or any other situation that requires changes to the airspace structure and procedures. Similarly, when the ANSP restricts access to a section of airspace or creates a temporary flight restriction (TFR), the UASP will factor in this change when assigning routes with flight authorizations. Some changes to airspace structures will be time-based and scheduled to strategically meet traffic demands, while others will be made dynamically as the need arises.

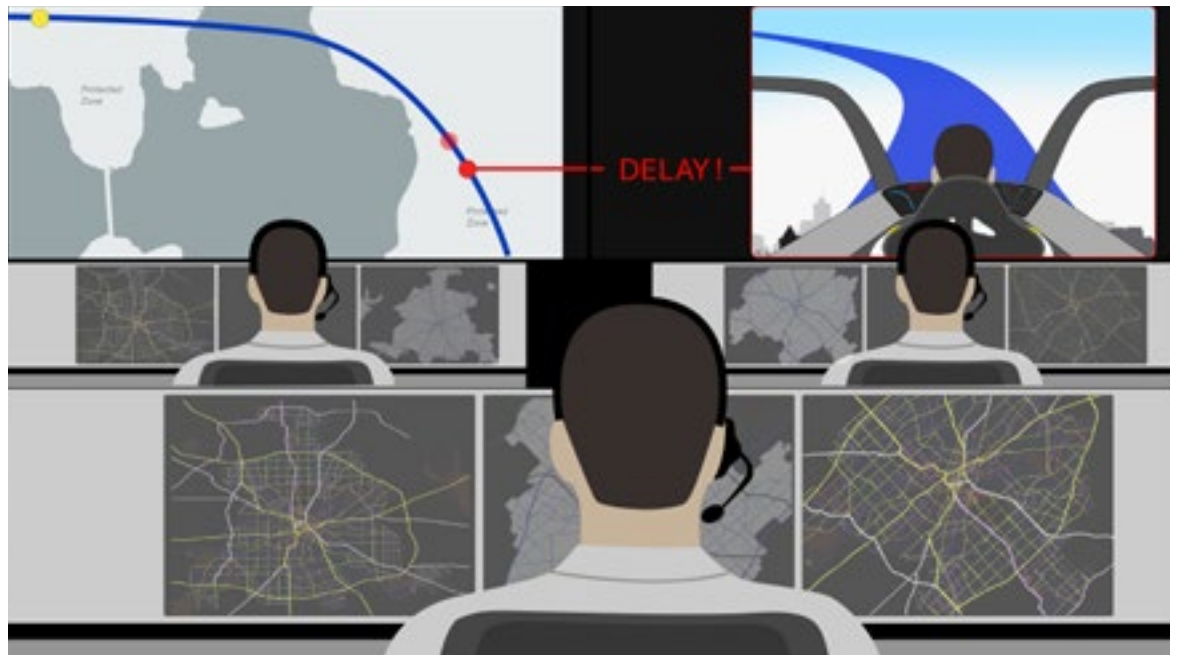


Dynamic airspace management will be a core service that enables continuous and flexible UATM operations.

Particularly in emergency situations, dynamic airspace management will be a critical service. The UASP will shift airspace structures as necessary and notify airspace operators of an emergency through any means of communication that matches the urgency of the situation. Noncritical adjustments to airspace structures will be made and reflected through data updates in the information exchange. During off-nominal situations where messages need to be disseminated urgently, communications may be delivered via voice communications.

## CONFORMANCE MONITORING

ENSURING FLIGHTS CONFORM TO FLIGHT AUTHORIZATIONS AND ASSISTING PILOTS DURING OFF-NOMINAL SITUATIONS



The conformance monitoring service will be a critical part of UATM operations. The highly dynamic nature of the airspace means that if an aircraft fails to conform to a flight authorization, particularly in a

dense route or corridor, the failure may have a negative impact on safety and efficiency. From departure until landing, the UASP automation will monitor the conformance of each UATM flight to the authorized route

and 4-D metering requirements. If the UASP automation predicts that a metering requirement will not be met, it will prompt the fleet operator and pilot to adjust the speed, route, or altitude of the flight so it remains in conformance to its 4-D requirements.

A mix of beacon (cooperative surveillance) and sensor (noncooperative surveillance) systems will monitor traffic and the location of aircraft in the UASP airspace. These surveillance systems will also interact with counter-UAS (C-UAS) systems to detect any unauthorized flights that may pose a threat to traffic.

UATM services will strive to be highly automated and will continue to evolve as the aviation industry develops new technologies. Advancements in avionics will continue to improve the conformance capabilities of UAM aircraft. These improvements will improve navigation precision and conformance to 4-D flight requirements, which

will make UATM safer for all stakeholders. Periodically, particularly during emergencies and off-nominal situations, tactical conflict resolution will still be required. When these situations occur, the human operators in the UASP will assist pilots to execute contingency plans that protect passengers and crew from other aircraft and obstacles.

**From departure until landing, the UASP automation will monitor the conformance of each UATM flight to the authorized route and 4-D metering requirements.**

All of these UATM services work as an interdependent suite that ensures the UAM system works efficiently, safely, and securely as operational conditions evolve. Figure 1 illustrates the interdependencies of the six UATM services.

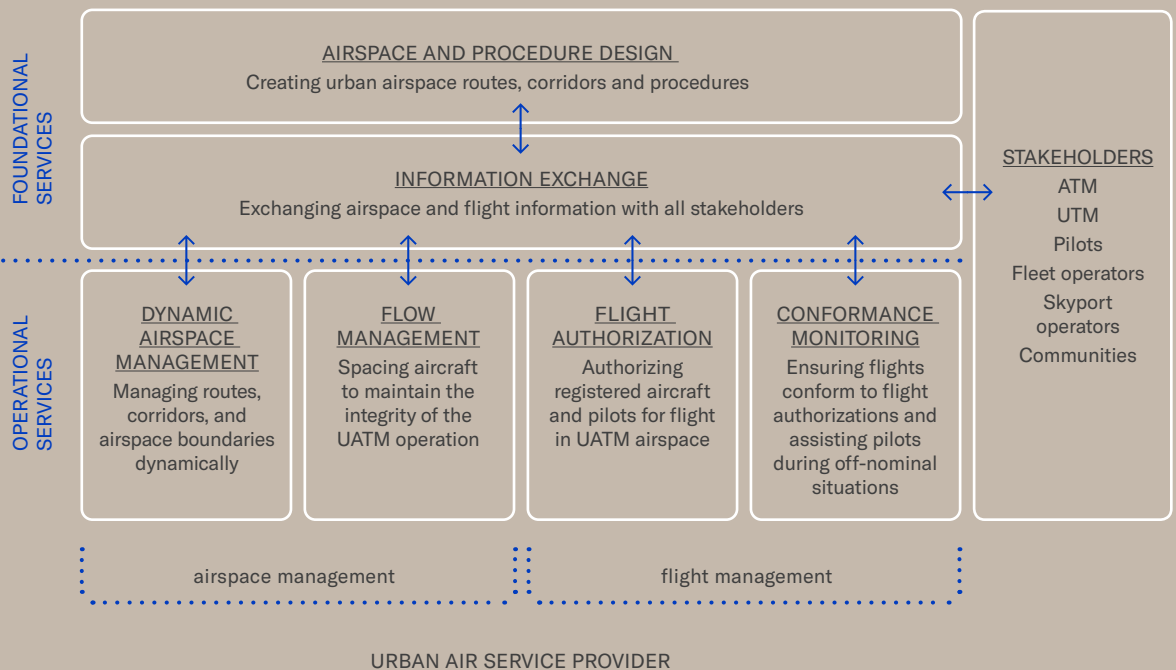


FIGURE 1. INTERACTIONS AND INTERDEPENDENCIES ACROSS THE SIX UATM SERVICES

# ENABLING TECHNOLOGIES FOR UATM

While UATM will be procedures-based first and foremost, it will rely on a complex array of technologies to deliver the suite of UATM services. As these technologies evolve, so will UATM services. This section highlights some of the key technologies needed to build a dynamic UATM system.

Each service is enabled by primary technologies that directly deliver the UATM service. In turn, these primary technologies rely on foundational or enabling technologies that deliver the relevant foundational data. Table 2 presents a service-technology traceability chart that describes the primary and enabling technologies that support each UATM service. Each service is linked to a set of primary technology implementation and the foundational/enabling technologies that are needed to support the primary technology. Some of these foundational technologies can be found in modern airspace systems currently being implemented around the world. The following technology areas warrant special attention and are discussed in detail:

- ① Target/traffic information
- ② Networks
- ③ Weather systems

Technological evolution is expected to enhance the UATM system and gradually support increased airspace capacity over time. In the end, we believe the UATM system will be a dynamic ecosystem of technologies that will monitor, manage, and communicate all facets of urban flights from departure to landing.

The anticipated rise of semi- and fully autonomous eVTOLs will require the UATM system to be scalable in several ways. Technological evolution is expected to enhance the UATM system and gradually support increased airspace capacity over time. In the end, we believe the UATM system will be a dynamic ecosystem of technologies that will monitor, manage, and communicate all facets of urban flights from departure to landing. This ecosystem will keep passengers and cargo safe while they move efficiently and expeditiously throughout the urban airspace.



SERVICE DESCRIPTION	PRIMARY TECHNOLOGY IMPLEMENTATION	FOUNDATIONAL/ENABLING TECHNOLOGIES
AIRSPACE AND PROCEDURE DESIGN	<p>Airspace and Procedure Design will be implemented by:</p> <ul style="list-style-type: none"> <li>• Big Data Analysis Tools</li> <li>• Geographic Display Tools</li> <li>• Simulation Tools</li> <li>• Airspace Structure Databases</li> </ul>	<p>The following enabling technologies are needed to support input for Big Data Analysis Tools:</p> <ul style="list-style-type: none"> <li>• Traffic Information Systems</li> <li>• Weather Information Systems</li> <li>• Other Information Systems (i.e., Demographic Information Systems)</li> </ul>
INFORMATION EXCHANGE SERVICES	<p>Information exchange services will be implemented by:</p> <ul style="list-style-type: none"> <li>• A ground-ground UASP network with advanced network technologies</li> <li>• A ground-air UASP network with wireless communication nodes in the air (avionics) and on the ground (radios)</li> <li>• Secure gateways to interface with external networks</li> </ul>	<p>The following enabling technologies are needed to support external information exchange:</p> <ul style="list-style-type: none"> <li>• ANSP networks</li> <li>• UTM networks</li> <li>• The internet</li> </ul>
FLIGHT AUTHORIZATION	<p>Flight authorization will be implemented by:</p> <ul style="list-style-type: none"> <li>• Servers accessible through the information exchange</li> <li>• Flight authorization databases</li> </ul>	<p>The following enabling technologies are needed to support flight authorization:</p> <ul style="list-style-type: none"> <li>• Target/traffic information systems</li> <li>• Weather information systems</li> <li>• Flow management systems</li> <li>• Airspace structure databases</li> <li>• Information exchange systems</li> </ul>
FLOW MANAGEMENT	<p>Flow management will be implemented by:</p> <ul style="list-style-type: none"> <li>• Big Data Analysis Tools</li> <li>• Flight management applications for manual control situations</li> </ul>	<p>The following enabling technologies are needed to support flow management:</p> <ul style="list-style-type: none"> <li>• Target/traffic information systems</li> <li>• Weather information systems</li> <li>• Flight authorization databases</li> <li>• Information exchange network</li> </ul>
DYNAMIC AIRSPACE MANAGEMENT	<p>Dynamic airspace management will be implemented by:</p> <ul style="list-style-type: none"> <li>• Airspace management applications with decision support capabilities</li> <li>• Big Data Analysis Tools</li> <li>• Airspace structure databases</li> </ul>	<p>The following enabling technologies are needed to support dynamic airspace management:</p> <ul style="list-style-type: none"> <li>• Weather information systems</li> <li>• Flight authorization database</li> <li>• Flow management systems</li> <li>• Information exchange network</li> </ul>
CONFORMANCE MONITORING	<p>Conformance monitoring will be implemented by:</p> <ul style="list-style-type: none"> <li>• Flight monitoring applications with automation capabilities</li> </ul>	<p>The following enabling technologies are needed to support conformance monitoring:</p> <ul style="list-style-type: none"> <li>• Target information systems</li> <li>• Flight authorization database</li> <li>• Information exchange network</li> </ul>

TABLE 2. SERVICE-TECHNOLOGY TRACEABILITY CHART

## TARGET/TRAFFIC INFORMATION

UASPs must utilize next-generation surveillance technologies for monitoring urban air traffic in real time. The primary foundation for urban air traffic surveillance will be GNSS-enabled technologies, which will be tailored to work well in low-altitude, urban areas. However, the surveillance system will have redundancies in place in the event of a GNSS failure. Alternative position, navigation, and timing (PNT) technologies will play a role in ensuring reliable telemetry. Multilateration technologies can leverage the communication channel while other completely independent regional or wide-area locational services can provide additional sources for target position validation.

Position tracking for urban air vehicles will use an Automatic Dependent Surveillance-Broadcast (ADS-B)-like cooperative surveillance technology that tracks airborne vehicles to within one-meter accuracies. Studies have shown that reuse of ADS-B for UAS and/or UATM has many challenges to overcome. Some models suggest ADS-B reuse can be achieved by simply tweaking ADS-B parameters for UATM (e.g., transmission power). However, the underlying assumptions of such models are not easily validated, and there is considerable risk if those assumptions do not come to fruition. The guesswork can be obviated through establishment of an ADS-B analogue that operates at a different frequency that is still within the protected aeronautical radionavigation spectrum. This approach mitigates the risk of impacting existing or future ADS-B system implementations.

Regardless of the specific technology, urban air traffic will broadcast real-time state vector information to ground-based receivers where the data will be processed and forwarded to UATM systems. Variants of these technologies

are already deployed in modern ATM systems today and will help to mitigate the risks of spoofing/jamming. Storage of target track data will enable big data analytic capabilities for deriving predictive tracking models and self-learning algorithms. Accurate target forecasting is essential to bringing about trajectory-based operations (TBO) and will be discussed further below.

The primary foundation for urban air traffic surveillance will be GNSS-enabled technologies, which will be tailored to work well in low-altitude, urban areas. However, the surveillance system will have redundancies in place in the event of a GNSS failure.

## NETWORK TECHNOLOGIES

To handle the massive amount of data that will be collected, processed and distributed, UATM will employ high-bandwidth network capabilities. These capabilities will use both wired and wireless communication protocols based on the location of assets and the demand placed on the overall system. Moreover, the ground systems will be hosted in a cloud-based, scalable environment that can dynamically respond to increases and decreases in demand without compromising overall network and computing integrity.

Broader latency challenges around the data can be expected and can be sufficiently addressed with modern network architectures.

Advanced, software-defined networks will offer the ability to scale communication resources of a geographical area based on real-time demand for UATM operations. Emerging wireless communication standards, such as 5G cellular and high-bandwidth Ka and Ku satellite connections, are touting unprecedented data throughput to users in the near future. While some of these standards are not completely mature yet (e.g., 5G), they will be fully developed by the 2025–2030 time-frame. The extent to which these technologies will support UATM is unclear, but they will likely play some role in moving data between air vehicles and ground systems.

Ground capabilities, from high-capacity fiber to advanced middleware, will enable seamless data integration across the entire urban air service platform, including key stakeholders such as local and state governments and ANSPs. Communication with external networks will, of course, require secure network gateways. Vehicles will act as communication nodes on the network. Not only will they send and receive data for their flight but they will also enable echo communications from other vehicles, thereby creating a dynamic wireless mesh network that will increase overall network coverage and efficiency. The ability to create this pseudo-mesh network in the air will largely depend on vehicle equipage; it may be limited at first. However, over time, vehicles will become better equipped and therefore better able to support networking capabilities in the air. In the future, regulators may even enforce equipage mandates to ensure vehicles support the overall system architecture. Even if regulators do not, UASPs will most likely establish minimum requirements to operate in the airspace.

**As with any safety critical network, ensuring Confidentiality, Integrity, and Availability (CIA) is a natural concern. To address these concerns, the safety and security principles for UATM networks will leverage those used for ATM.**

All communications will employ a standards-based approach to ensure interoperability between systems provided by various manufacturers and vendors. This will provide vehicle manufacturers, Fleet Operators and service suppliers with flexibility in their system design while meeting the communication requirements of the UASP.

As with any safety critical network, ensuring Confidentiality, Integrity, and Availability (CIA) is a natural concern. To address these concerns, the safety and security principles for UATM networks will leverage those used for ATM. Those principles are proven as they have resulted in extremely robust and secure networks, which are sometimes categorized as “aviation grade.” As such, the UATM networks will involve many of the same security-focused technical implementations used in ATM networks, such as equipment redundancies and access control by Authentication, Authorization, and Accounting (AAA). Moreover, each networking technology will need to undergo thorough risk evaluations prior to integration. This security approach, among many others, will keep the UATM information exchange network secure throughout its lifecycle.

## WEATHER TECHNOLOGIES

In addition to traffic information, weather information is another important factor for the Flight Authorization process. Modeled flight trajectories will be compared against current and forecasted weather to ensure that each flight has a low risk of encountering hazardous weather. To support this functionality, the UASP will gain access to existing weather information systems for both current and forecasted weather data. A benefit from operating in dense urban environments is the large presence of weather sensors and forecast systems supplying a multitude of customers.

In some cases, the UASP will also deploy additional weather sensors to create an integrated weather observation network specifically tailored to low altitude areas in urban environments. As an example, skyports can provide a platform for hosting hyper-accurate micro-climate sensors that will provide UASP operators real-time conditions for every skyport in the urban area. Over time, eVTOLs will act as flying weather sensors. This ‘crowd-sourced’ network of weather sensors can provide a more complete picture of weather in urban airspace. Ultimately, these new weather sensors can provide UASPs with new degrees of weather accuracy and confidence necessary to support the anticipated volume of urban air traffic. Advanced forecast analysis tools will also be employed by UASPs to predict low altitude weather phenomena for each flight.

Over time, eVTOLs will act as flying weather sensors. This ‘crowd-sourced’ network of weather sensors can provide a more complete picture of weather in urban airspace. Ultimately, these new weather sensors can provide UASPs with new degrees of weather accuracy and confidence necessary to support the anticipated volume of urban air traffic.

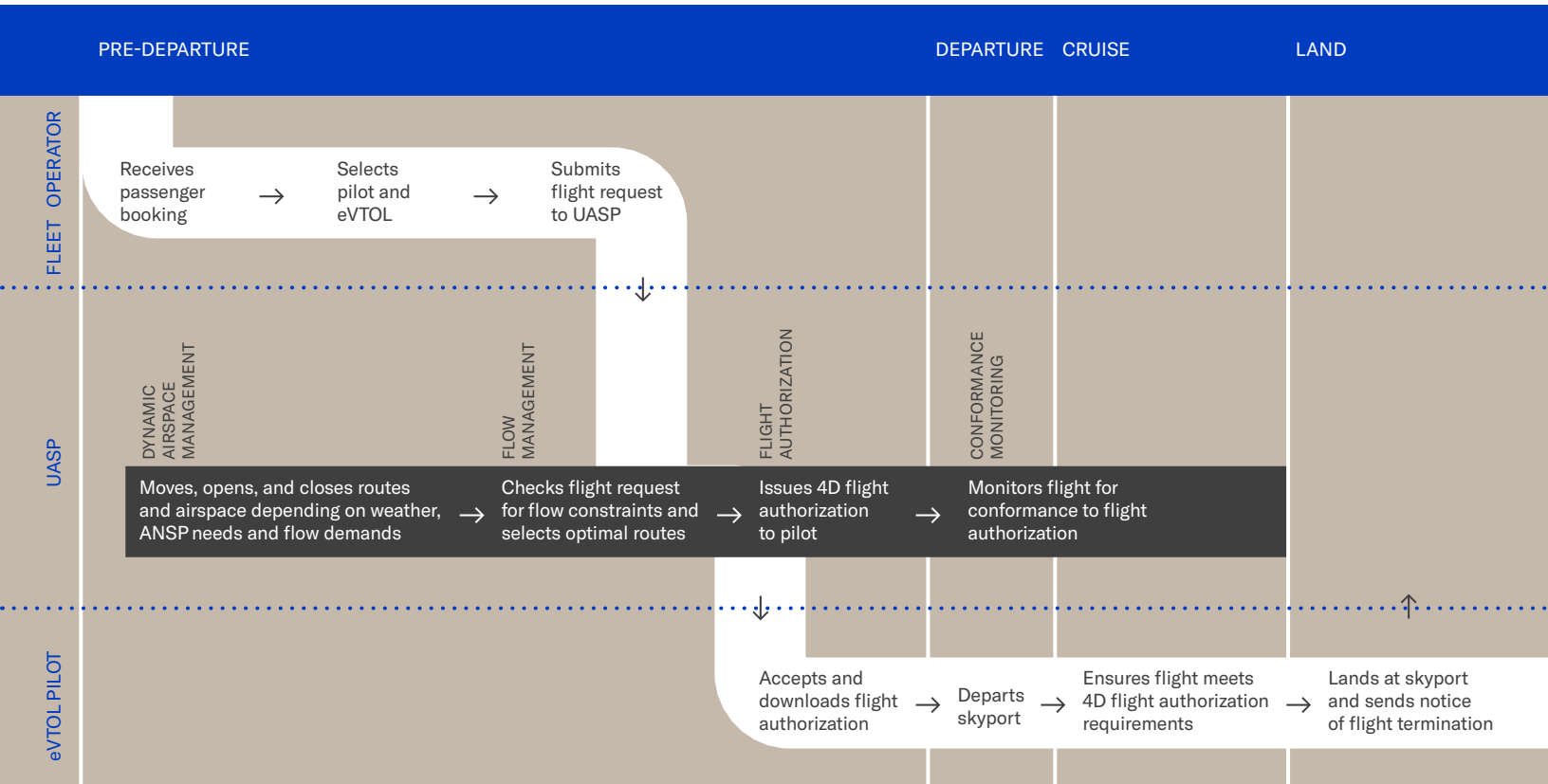
While weather forecast capabilities will prevent many flights from experiencing hazardous conditions, the flight authorization process will ensure there are appropriate contingencies in place in case of unexpected hazardous conditions, which may or may not be weather related. In general, the evolution of enhanced forecasting tools and observational weather sensors are expected to further increase predictability of urban air flight operations. Increased predictability means better fidelity, which ultimately enables scalability of UAM.

# USE CASES

The following use cases demonstrate how UATM works in realistic scenarios during each phase of flight, starting from pre-departure to departure, cruise, and land. These scenarios describe stakeholders' actions and interactions during a:

- ① Flight across the city
- ② Medical emergency during a flight
- ③ Reclamation of the airspace with short notice

The diagram below presents a high-level summary of the interactions between the fleet operator, the UASP, and the pilot over the different phases of a typical flight.





## SCENARIO 1: FLIGHT ACROSS THE CITY

An eVTOL travels across an urban area.

### PRE-DEPARTURE

The fleet operator receives a request for a flight and then begins to identify an available eVTOL and pilot. The fleet operator assesses skyport availability, flight routes, weather, and any other information necessary for assigning a flight to a suitable pilot and aircraft. After selecting an eVTOL and a pilot and coordinating with the skyport operator, the fleet operator applies for a flight authorization by submitting a flight request to the UASP. The flight request states the departure skyport, the destination, and the departure time. It will also identify the pilot and aircraft.

Upon receiving the flight request, the UASP begins finding an optimal route. First, the UASP confirms the aircraft and pilot are

registered for UATM operation and checks the certification of the aircraft and crew to fly in corridors that require high-level CNS capabilities. The UASP coordinates with the departure and arrival skyport operators to ensure TOL pads are available at the assigned departure and arrival times. Using predictive analysis, the UASP checks the flight request against numerous factors, including traffic flows, weather, and airspace restrictions. The UASP may also coordinate with the ANSP and USSs as needed to identify an acceptable route.

The UASP approves the flight request and sends the flight authorization to the pilot and fleet operator via digital messaging. The



flight authorization contains the approved route, departure time, arrival time, corridor entry place and time, 4-D metering requirements, and the assigned TOL pad. If a problem with the flight request had been found, the UASP would have recommended a change to the fleet operator. The recommendation may include using a nearby skyport or an amended departure time. Alternatively, the UASP may reject the flight request if no acceptable amendments can be found. In the end, the UASP will always provide a recommendation, but it will be up to the fleet operator and pilot to accept the recommendation.

## DEPARTURE

The assigned eVTOL is already at the skyport when the pilot arrives. While passengers and goods are loading onto the flight, the pilot accepts the flight authorization and then downloads it from the network into the aircraft's navigation system. The aircraft departs from the skyport at its assigned time. As the flight departs, the network updates with a notice of the flight's departure time generated from the aircraft's avionics. The skyport operator will access this flight information to ensure the TOL pad remains available when the aircraft lands and will share this information to inform fleet operators about TOL pad availability at the skyport.

## CRUISE

During the flight, the avionics, beacons, and sensors provide the UASP and nearby aircraft that have cooperative surveillance systems with updates about the aircraft's position and

speed. The aircraft's detect-and-avoid functionality supports the pilot's situation awareness about nearby aircraft and obstacles. The pilot continually scans the avionic displays to ensure conformance to the assigned route and to monitor the status of the aircraft systems, as well as meteorological updates. The pilot also scans for any digital messages from the UASP or the fleet operator.

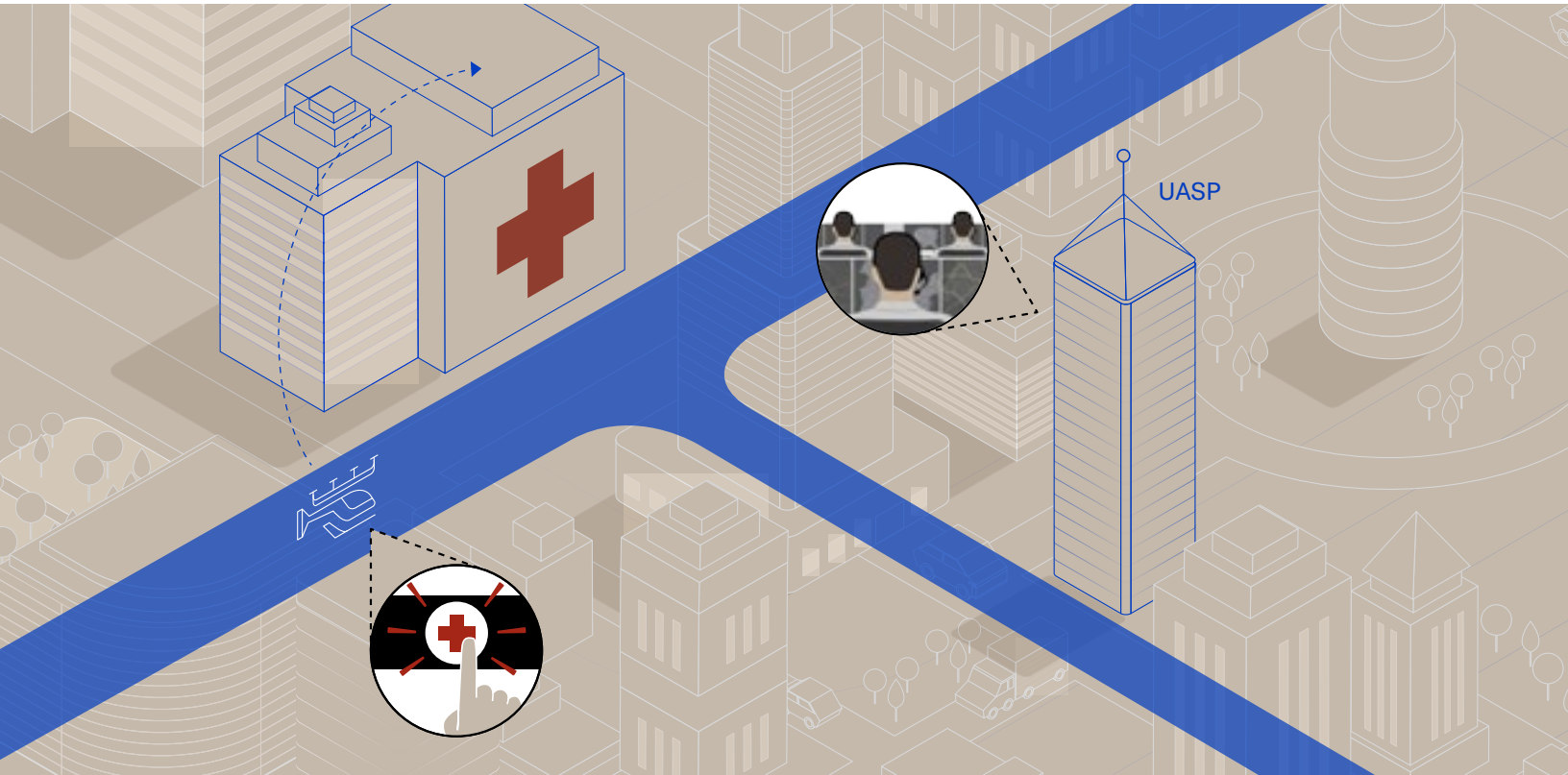
While the aircraft is in flight, the UASP monitors its conformance to the assigned route and 4-D requirements. If the UASP predicts that an aircraft is at risk of missing its 4-D waypoint, the UASP will send a digital message to prompt the pilot to adjust the speed, route, or altitude as needed.

## APPROACH

As the aircraft approaches the destination, the pilot ensures the TOL pad and surrounding airspace is free of hazards such as obstacles or gusty winds. Prior to landing, the skyport operator may send a digital message to the pilot to assign the flight a specific TOL pad.

## LANDING

The pilot lands at the designated TOL pad within the assigned time window. Depending on the skyport, the pilot will then clear the TOL pad so that other flights can land on the pad. The passengers disembark the aircraft and exit through the skyport terminal. The pilot sends a notice using the network to indicate that the flight terminated safely at its destination. This information is updated and shared with all network users.



## SCENARIO 2: IN-FLIGHT MEDICAL EMERGENCY

The Pre-Departure and Departure events are the same as those in Scenario 1. However, when a medical emergency is declared during the Cruise phase of flight, the events unfold differently. This scenario also assumes that procedures are in place to ensure that TOL pads are available along the route in case of emergencies.

### CRUISE

During flight, a passenger experiences a medical issue and the pilot declares an emergency. The pilot needs to divert and provide the passenger with immediate medical assistance. Using voice communications services, the pilot contacts the UASP and requests an immediate reroute to a hospital.

The UASP analyzes the request and uses the information exchange system to search skyport data for the closest hospital with an available TOL pad. The UASP generates an updated flight authorization that reroutes the aircraft to a nearby hospital. The updated flight authorization is sent to the pilot and fleet operator via a digital messaging system. The pilot assesses the reroute, accepts the new flight authorization, and downloads it to the flight management system.

Once the flight authorization is accepted, the UASP flow management system assesses how the emergency impacts the airspace. Priority is given to the aircraft experiencing the in-flight medical emergency, but the flow management system minimizes the reroutes required of the other vehicles sharing

the airspace, such as passenger-carrying aircraft and sUASs operating in adjacent airspace. Continuous, accurate, and timely information exchange between all traffic management systems, along with established procedures, is critical to maintaining the safety of the airspace.

While the pilot flies to the hospital, the UASP notifies the medical facility of an impending arrival. The UASP also monitors the flight and stays in contact with the pilot until the flight lands.

## LANDING

The pilot lands at the hospital and is met by medical personnel. The other passengers disembark and the pilot clears the TOL pad to allow other aircraft to land. The pilot sends a notice to the network to indicate that the flight terminated safely at its destination. This information is updated and shared with all network users. The fleet operator then coordinates with the skyport operator at the originally intended destination and submits a new flight request to the UASP, so that the pilot may transport the remaining passengers to the original destination with a new flight authorization.





## SCENARIO 3: RECLAMATION OF THE AIRSPACE WITH SHORT NOTICE

The ANSP needs to reclaim control over a section of UATM airspace and declares a TFR. The UASP geofences the area and reroutes traffic.

### RECEIVING THE TFR ALERT

ATM informs the UASP that a TFR has been activated over a section of low-altitude airspace. In collaboration with ATM, the UASP identifies the lateral and vertical boundaries of the TFR area and the affected routes/corridors.

### REROUTING FLIGHTS

The UASP informs affected skyport operators of the TFR and identifies the flights currently en route into the affected area. No new flights are authorized for entry into the TFR zone. To keep UATM traffic flowing efficiently, the

predictive analysis tools identify optimal alternate routes for the current traffic and use data from the information exchange system to find skyports near the affected area that can accommodate any diverted flights. The UASP collaborates with skyport operators to identify alternative departure and TOL pads and ensure that emergency TOL pads are available during the TFR. The UASP also notifies all fleet operators and pilots about the suspended operations in the TFR by broadcasting a digital message and updating the information exchange network. As the UASP receives new flight requests, the UASP analyzes the requests and issues alternative destinations if a requested destination is within the TFR.



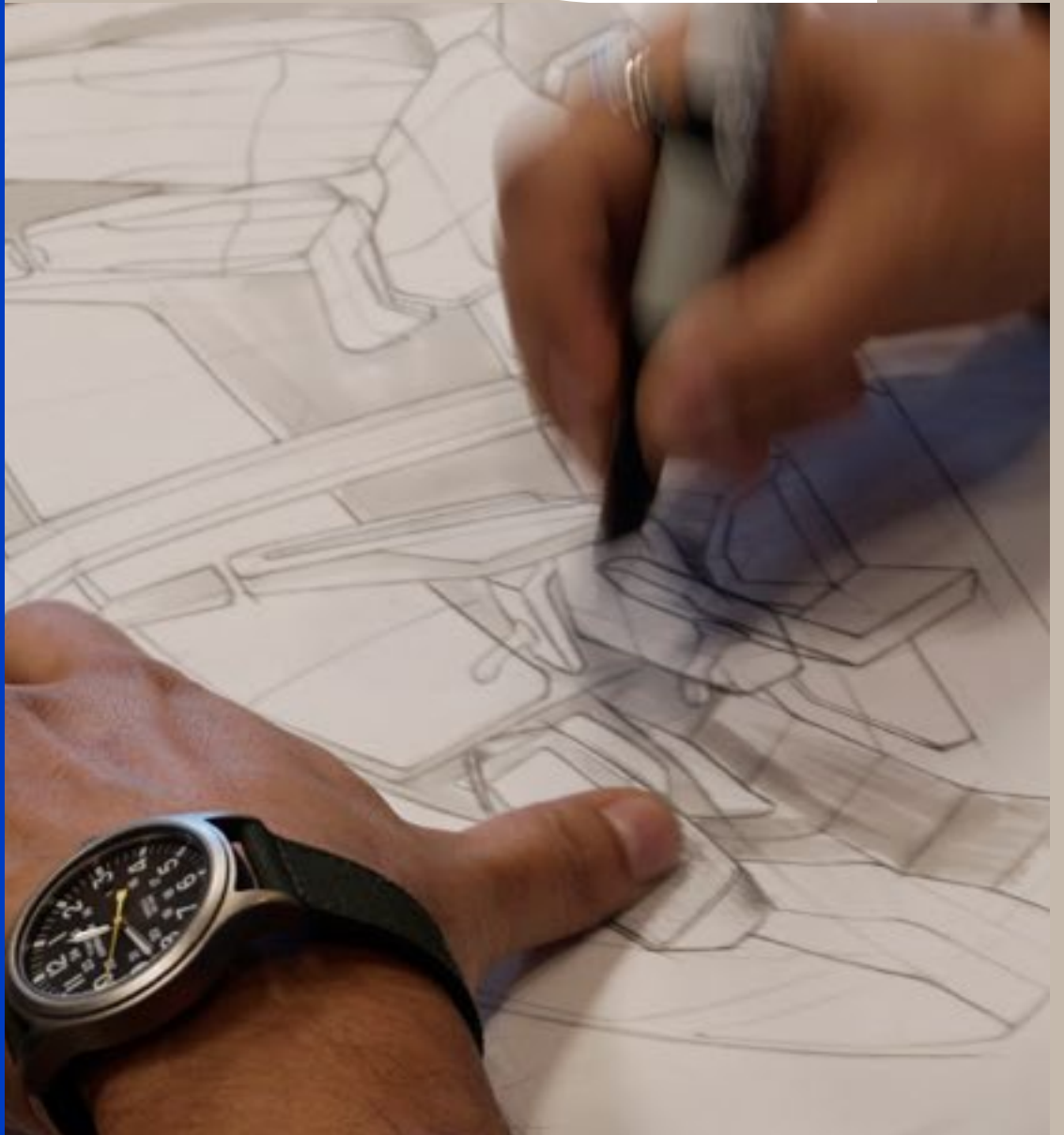
## FLYING A REVISED ROUTE

All flights that are en route to the reclaimed airspace receive a revised flight authorization via digital messaging or very high frequency (VHF) radios if they are not equipped with digital messaging avionics. Each pilot who electronically receives a revised flight authorization acknowledges the message and then downloads the new flight authorization into the aircraft Flight Management System.

The pilots inform their passengers of the TFR and the need to reroute. If a destination is within the TFR area, the pilots inform their passengers of the assigned alternate destination. Each pilot then continues the flight following the revised route. Meanwhile, the UASP monitors the rerouted flights to confirm conformance to each revised flight authorization.

## LANDING

For those flights that are rerouted to an alternate TOL pad, the pilot will land, and the passengers will disembark. The UASP will have rerouted the flight to a skyport near but outside the TFR zone. The pilot sends a notice using the network to indicate that the flight terminated safely at its destination. This information is updated and shared with all network users. In consultation with the fleet operator, the pilot creates a plan to reposition the aircraft for the next flight.



PART 3

# PREPARING FOR TOMORROW

## Collaboration must start today if we are to reap the benefits of UAM tomorrow.

In the next decade, urban air travel will become a mainstream experience. Commuting to connect with family and friends will demand less time and effort. Delivering goods and services to customers will be more efficient, and responding to emergencies will be less encumbered by traffic congestion.

As this industry unfolds, communities, regulators, ANSPs, and other stakeholders have the opportunity to plan and shape the future of UAM. Stakeholder involvement throughout all stages of development will be crucial in designing how we move about urban areas and the infrastructure that supports that future.



## COMMUNITY INVOLVEMENT AND ENVIRONMENTAL CONSIDERATIONS

Community leaders, educators, and city planners will soon have a chance to participate in consultations and forums with stakeholders from private industry and government to ensure that the UATM system is designed with consideration for community issues. Through social media and face-to-face meetings, they will identify the areas with the highest demand, discuss how to operate most efficiently, and plan ways to minimize noise levels and emissions. Along with ATM interactions and the ability to achieve desired flight densities, noise management, community acceptance, and accessibility of ground infrastructure have been identified by

aviation experts as the biggest constraints to the growth of the UAM industry (Vascik & Hansman, 2017a; ICAO, 2017).

Stakeholder involvement throughout all stages of development will be crucial in designing how we move about urban areas and the infrastructure that supports that future.

UATM airspace and procedure design will play a lead role in ensuring that these considerations are appropriately addressed. ANSPs and regulators will play a pivotal role in ensuring that both UAM operators and community considerations are taken into account. This will include facilitating the development and implementation of community agreements and legislation to ensure that appropriate noise management occurs and that the UAM industry develops in line with existing noise abatement regulations. Similarly, simulation testing should be conducted early to provide risk assessments for risk mitigation and analysis. Through the use of data analysis tools, industry developers and government regulators can define the urban routes best suited for on-demand transport and transport of cargo and medical services. Some factors that will be considered are weather hazards, obstacles, avoidance of environmentally sensitive areas, and areas where additional safety redundancies are required, particularly for high-volume routes.

Environmental considerations will be a significant part of preparing for the growth of urban aviation. ANSPs and regulators will play an important role in helping aircraft operators manage both their emissions and noise impacts. The UASP will oversee the urban airspace day to day, ensuring that these considerations are appropriately addressed. Minimizing energy usage, and the resulting emissions, directly aligns with UAM operators' objectives to perform operations in the most efficient manner. Flight efficiency is critical

for eVTOL operations to achieve operational viability, as well as emissions minimization. UATM will play a key role to ensure that routes are as efficient as possible and that congestion is minimized. There may be opportunities to design routes to ensure that noise is either concentrated over low population areas or spread out to ensure that community areas receive respite.

**ANSPs and regulators will play a pivotal role in ensuring that both UAM operators and community considerations are taken into account.**

Another key issue that impacts both flight efficiency and noise management is the location of skyports. In these decisions and the resultant routes, the urban aviation industry will need to adopt the ICAO balanced approach to aircraft noise management (ICAO, 2008). This approach looks to ensure that noise is tackled at a specific location using a variety of approaches, including land-use planning and management, noise abatement, operational procedures, and operating restrictions. Fleet operators, skyport operators, and the UASP will need to collaborate to consult and engage with the community and government to mitigate the potential environmental constraints to urban aviation operations.



# SAFETY AND SECURITY IN THE UATM SYSTEM

The safety and security standards of the aviation industry are high, and the challenge for UATM to meet, or even exceed, this standard is considerable. Without a safe, secure, and resilient UATM system, the industry will not grow to its full potential, and the benefits to the community and economy will not be fully realized. Ongoing risk analysis and technological evolutions in both aircraft and traffic management systems will continue to shape and reshape the industry. Beyond physical safety, the UAM industry will need a robust commitment to cybersecurity, with cyber-resilient systems end-to-end. With continued advancements in autonomy, along with the technological interdependencies the UATM system will contain, cybersecurity will be critical for ensuring the safety of both aircraft and the urban public below.

The UASP will play a pivotal role in enhancing and maintaining the safety of the UAM industry. The UASP's safety management system (SMS) will capture real-time safety reports that will inform continual safety improvement efforts. Using high-precision surveillance capabilities, the UASP will monitor the adherence of UAM aircraft to flight authorizations. Furthermore, these data will provide stakeholders with insight that can be used to proactively improve each fleet's operational safety performance. These data will also allow regulators to confirm that traffic complexity is well managed and thus support the safety case for higher capacity operations in the future. Early research and analysis will assist the UASP, aircraft manufacturers, fleet operators, regulators, and ANSPs to identify where technological and procedural risks

exist and develop robust mitigation strategies. Many advances in automation will be proven out through data that is collected by the UASP during UAM operations in UATM airspace. Operations in early adopter cities will provide data that will help regulators understand what separation requirements will be appropriate for future implementations.

**Beyond physical safety, the UAM industry will need a robust commitment to cybersecurity, with cyber-resilient systems end-to-end.**

Given that the UAM industry will introduce a new type of aircraft into a new operational context, safety analyses using a wide range of strategies, including fast-time simulations, human-in-the-loop experiments, failure modes and effects analysis, and other types of risk analysis will be critical to identifying where new opportunities for system failures and human errors may arise. Accordingly, results from these analyses will inform the development of risk mitigation strategies. Safety in the ATM terminal environment will also need to be addressed in detail, as this vision mainly covers the relationship between the UASP and fleet operators. However, the UATM system will play a critical role in enabling communication between all stakeholders in UAM who will need to set standards, protocols, and procedures.

# ONWARD

The next chapter in urban transportation has already commenced. Aircraft manufacturers are already taking to the skies and testing their latest eVTOL models. Architects are busy designing our future skyports. Battery engineers are trialing new technologies that will power future flights. In short, the revolution in urban mobility has quietly arrived.

Designing an urban airspace system that melds these aircraft with other airspace users will require collaboration and a bold, unwavering commitment to safety. We have the innovative tools and the insight

to address the upcoming challenges that eVTOLs will bring to the urban environment, but we need to begin collaboration and consultation now if we are to create a smart, integrated, and thoughtful airspace solution. A future is possible where we can look up and see eVTOLs coexisting with other aircraft, where an on-demand flight can take us aloft and deliver us safely to our workplaces, families, and friends.

Come with us—work with us—as we start the journey to transform the vision of Flight Plan 2030 to a reality.

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# ACRONYMS

AAA	Authentication, authorization, and accounting
ADS-B	Automatic Dependent Surveillance–Broadcast
AI	Artificial intelligence
ANSP	Air navigation service provider
ATC	Air traffic control
ATM	Air traffic management
CIA	Confidentiality, integrity, and availability
CNS	Communication, navigation, and surveillance
C-UAS	Counter unmanned aircraft system
eVTOL	Electric vertical take-off and landing vehicle
FIMS	Flight Information Management System
GA	General aviation
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
IATA	International Air Transport Association
PBN	Performance-based navigation
PNT	Position, navigation, and timing
SMS	Safety management system
sUAS	Small unmanned aircraft system
SWIM	System Wide Information Management
TBO	Trajectory-based operations
TFR	Temporary flight restriction
TOL	Take-off and landing
UAS	Unmanned aircraft system
UASP	Urban airspace service provider
UAM	Urban air mobility
UATM	Urban air traffic management
USS	UAS service supplier
UTM	UAS traffic management
VHF	Very high frequency

# GLOSSARY

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eVTOL	A new type of vertical take-off and landing aircraft that will be powered by batteries hybrid engines, and/or other new technology. It will transport two to six passengers across short- to mid-range distances. Some eVTOLs will look similar to a helicopter while other designs will be unprecedented.
Fleet Operator	An entity that operates one or more aircraft that provides UAM services in the low-altitude urban environment.
Skyport	A location where urban flights will arrive and depart. A skyport may have one or many Take-off/ Landing pads.
Skyport Operator	An entity that manages skyport services and the operation of take-off/landing pads.
Urban Air Mobility	On-demand urban air services that carry passengers and cargo across a metropolitan area.
Urban Airspace Service Provider	An entity that manages UAM traffic and provides UATM services over an urban area.
Urban Air Traffic Management	A system that will use strategically designed airspace structures and procedures to ensure urban flights remain safe and efficient while minimizing the impact on ATM.

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