Concept of Operations for Uncrewed Urban Air Mobility

Summary

Foreword

> **"We are embarked as pioneers on a new science and industry … Our job is to keep everlastingly at research and experiment, to adapt our laboratories to production as soon as practicable, to let no new improvement in flying equipment pass us by."**
>
> **–Bill Boeing, 1929**

Nearly a century after Bill Boeing's call to action, a massive air transportation system that safely transports people around the globe has been created, and even still his message rings true. Annually, over 46 million flights move more than 4 billion airplane passengers between cities, countries, and continents. Yet, the majority of the global population has never flown in an airplane.

A convergence of social dynamics, business models, sustainability goals, and technology are enabling a new chapter in aerospace. Air travel will become much more personal, accessible, and frequent as we normalize a new form of transportation in the skies. Advancements in autonomy, electric propulsion, and network connectivity have allowed a wave of inspiring inventions with immense potential to change aviation forever.

We are on a mission to establish safe and affordable, everyday flight for everyone. A whole-of-industry approach is needed with stakeholders in both the traditional and emerging aviation systems. Beyond the novel aircraft, an ecosystem will evolve to scale operations, repurposing aging infrastructure while inventing new societal norms for its use. Community trust and acceptance will be key.

This concept of operations for urban air mobility (UAM) is the culmination of studies by experts across Boeing, Wisk, Aurora Flight Sciences, SkyGrid, and other industry affiliates.* It specifically addresses a critical element to safely scaling up the tempo of UAM flight operations—enhanced automation and a shift in how we define the role of pilots. This document describes an approach to the transition from crewed to uncrewed flight that applies technical and operational innovations that are at once both evolutionary and pragmatic.

As inventors, leaders, and enthusiasts of UAM, we have an obligation to society and each other to build on the aviation successes of the past and to advance the highest safety standards. Together, we will build and shape this novel future ecosystem while continuously improving safety and efficiency. We invite your inputs and feedback to this concept of operations. This is a living document that will mature over time.

Here's to the next 100 years.

Brian Yutko
VP and Chief Engineer,
Sustainability & Future Mobility at Boeing

Gary Gysin
CEO of Wisk

*Wisk and SkyGrid are Boeing Joint Ventures.
Aurora Flight Sciences is a wholly owned Boeing subsidiary.

Feedback

As we build together, the industry will change shape and evolve. We invite your inputs and feedback to this concept of operations for uncrewed urban air mobility.

Please send an email with feedback to urbanairmobility@boeing.com.

Disclaimer: Please do not include any confidential information in your feedback. All feedback becomes the property of The Boeing Company.

Introduction

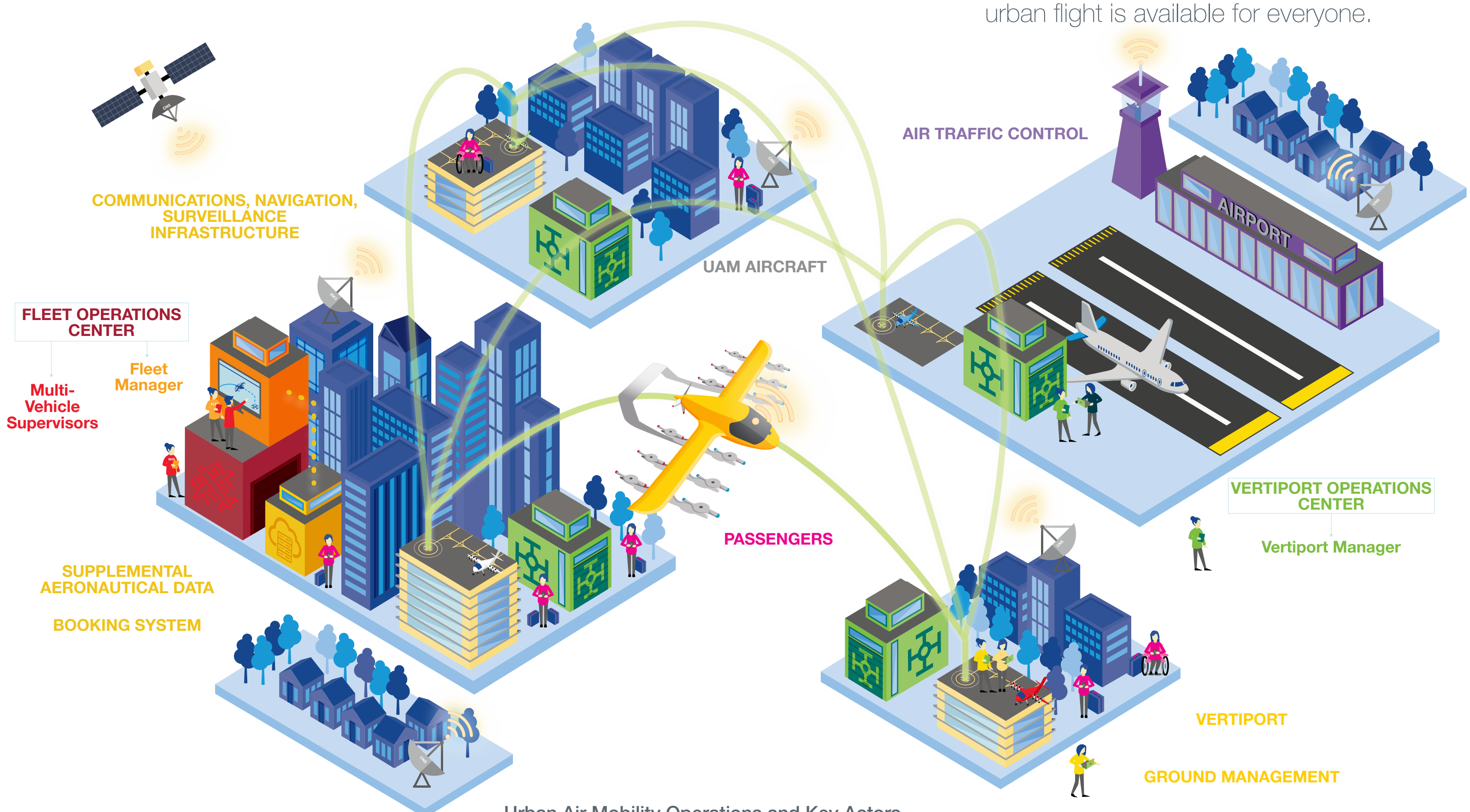
The purpose of this document is to introduce a Concept of Operations (ConOps) for uncrewed, passenger-carrying urban air mobility (UAM) operations that utilize air vehicles operating autonomously. This document outlines a high-level vision, in parallel with the detailed document,that includes technology regulatory and social recommendations to help make uncrewed UAM a safe reality.

This document aims to integrate uncrewed UAM aircraft into the United States National Airspace System (NAS) to create a pathway forward for more equitable access to mobility across socioeconomic levels by the end of the decade. This ConOps also intends to provide a blueprint for UAM operations globally.

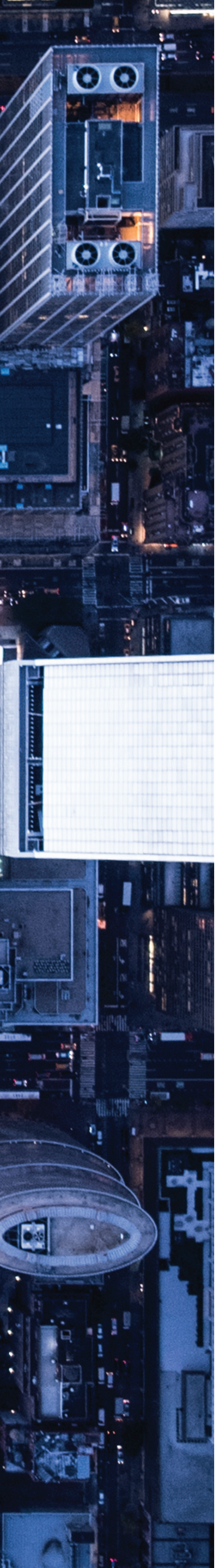
Advancements in the NAS that will safely enable new flight will primarily be derived by ongoing Air Traffic Management (ATM) investments. These ATM investments, especially within the U.S., are close to coming to fruition by the end of decade (i.e., mid-term) and offer a lower-risk path to safety-enabled UAM.

New flight rules will be needed for scalability of the broader UAM industry and this ConOps offers a mid-term flight rules solution as a transition and complement to far-term flight rules that will exist in the years that follow.

The ConOps is intended to facilitate stakeholder engagement and convergence on the underlying concepts presented. As stakeholder convergence is achieved and the concepts are solidified, technology development can proceed with minimal risk toward a future where safe and affordable urban flight is available for everyone.

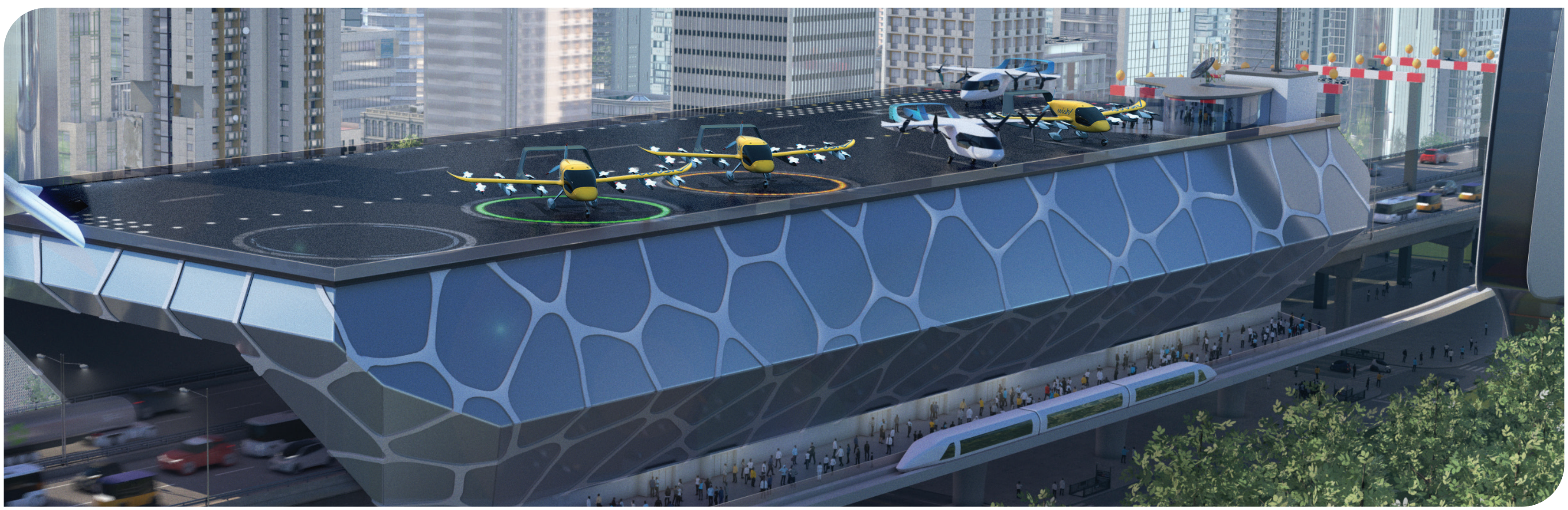


Urban Air Mobility Operations and Key Actors



Key Stakeholders

Stakeholders	Example	Role
Flying Public and Community	Long Beach Community Economic Council	Vocalize any environmental or societal concerns and potential impact of UAM on individual communities. Work with industry to effectively plan and implement changes to safely integrate UAM into the local airspace.
Regulatory Agencies	FAA, EASA, CAA	Work to support the safe integration of UAM into the airspace.
Trade Associations	AUVSI, AIA, GAMA, HAI	Work with industry to support national competitiveness and to further advance policies.
Standards Development Organizations	RTCA, EUROCAE, ASTM	Aim to develop industry consensus-based standards to be used as a basis for certification.
UAM Industry	Wisk, SkyGrid, Insitu, Aura, Skyports, Vertical, Joby, Altitude Angel, Eve	Develop the technology to advance the mobility industry—including aircraft, UTM systems, command-and-control links, vertiports, etc.
Traditional Airspace Users and OEMs	General/Business Aviation (incl. fixed-wing and helicopters), American Airlines, United, Delta, Boeing, Airbus	Work with UAM industry to identify solutions to safely integrate aircraft into airspace and partner on sustainable airspace opportunities.
R&D Testing Agencies	NASA, SESAR	Identify and support industry testing and promote collaboration to further advance and validate research.
Federal, State, and Local Policymakers	U.S. Congress, State Representatives, Mayors	Advance the level of safety in UAM and work with industry to develop a comprehensive integration strategy with increased innovation.



Key Principles and Assumptions

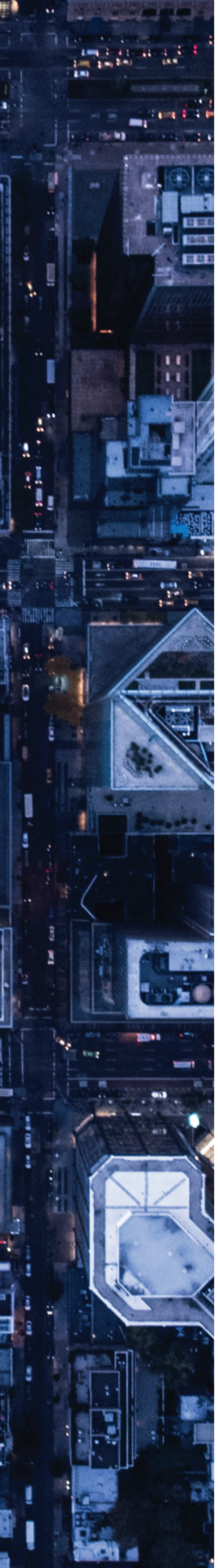
At the highest level, uncrewed UAM will be driven by the following principles and assumptions:

- **Safe, affordable, everyday flight for everyone:** This principle embodies one of the core tenets of Advanced Air Mobility (AAM) and will save passengers both time and money compared to current mobility. UAM is a subset of AAM and focuses on lower altitude operations within urban environments.
- **Business objectives:** The business model will be enabled by conducting day and night operations under visual or instrument meteorological conditions. In addition, high-throughput operations are anticipated, as are cost sharing for information and Communication, Navigation, Surveillance (CNS) services.
- **Ubiquitous flight autonomy:** The key to unlocking safe, everyday flight for everyone. To supplant traditional human aviation functions as well as human ATM functions of flight operation as well as ATM.
- **Scalability:** Autonomy will reduce the workload on air traffic controllers and vehicle operators to enable scalability of the UAM ecosystem.
- **Aircraft evolution:** UAM aircraft will be autonomous rather than remotely piloted aircraft. Onboard and/or ground-based detect-and-avoid systems will address interaction with traffic not managed by other ATM Function.
- **Cybersecurity:** UAM aircraft and associated systems require strong cybersecurity for protection and resilience against intentional and unintentional digital disruptions.
- **Airspace evolution:** The UAM aircraft ecosystem will not require novel airspace concepts beyond what is available today. Legacy ATM concepts and the underlying traffic management services offered by the current airspace structure, published procedures, and existing flight rules will be sufficient for UAM operations. However, it is recognized that any uncrewed UAM operations in the NAS will require airspace evolutions, primarily through rule-making as well as waivers and exemptions from the FAA.
- **Infrastructure evolution:** UAM vertiports will evolve to support new and current flight rules alongside electric UAM aircraft. Electrical grid improvements will ensure on-demand availability with capacity to support operations at scale.
- **Operator:** The onboard avionics suite will nominally execute flight duties while a “human-over-the-loop” supervisory station will serve as the final authority for flight execution. This will include the development of interfaces and procedures to employ onboard and multi-vehicle system autonomy.

Key Enablers

The information presented in this ConOps is the result of the convergence of enabling technologies such as battery and distributed propulsion advancements, near-unlimited computing power, and advances in automation systems. This convergence will support the adoption of:

- **Trajectory-based flight plans:** To provide flow management for timely traffic sequencing.
- **Comprehensive air and ground situational awareness:** To support optimized flight planning in the presence of weather, traffic congestion, airspace, and obstacle/terrain constraints.
- **Vertiport automation system:** To streamline vertiport capacity balancing and allocate real-time landing zone availability, which will help minimize ATC system interactions.
- **Command and control (C2) link infrastructure:** To provide reliable over-the-air C2 capabilities.
- **Detect-and-avoid and landing hazard avoidance functions:** To provide UAM aircraft with real-time conflict management capabilities.
- **Internet protocol (IP)-based communications:** To enable constant communication integrity monitoring between ATC operational centers and fleet operational centers (FOCs), as well as automated transfer capability as aircraft cross ATC facility boundaries.

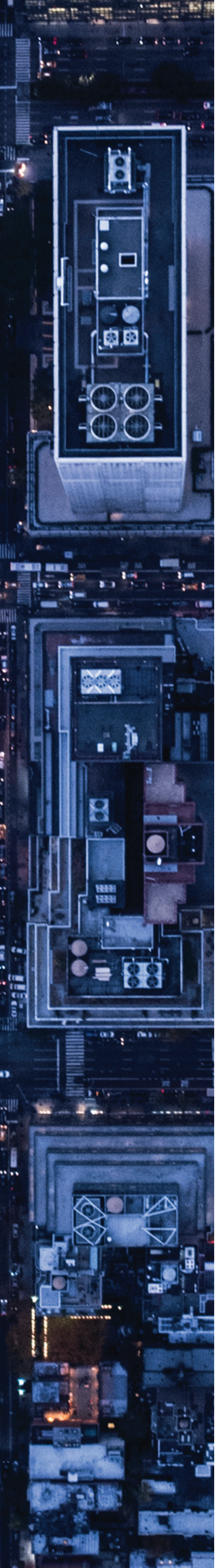


Establishing a Stepping Stone to Uncrewed UAM

This ConOps intentionally defines a future operational state that requires an evolution from how aircraft are operated today. While UAM aircraft are engineered to support this ConOps, they should be provisioned for the industry's vision of far-term operations.

Utilizing Safety Management System (SMS) principles, Boeing and Wisk aim to work with regulators on operational testing to achieve the proposed mid-term and far-term state. The adjacent table shows key principles and assumptions of the ConOps with the state of today's regulations. The remainder of this document, alongside the more detailed ConOps, describes operations as envisioned in the mid-term column.

	Current and Near-term UAM	**Mid-term UAM** (This ConOps)	**Far-term UAM**
Flight Rules	Visual Flight Rules (VFR) and Instrument Flight Rules (IFR).	UAM aircraft adhere to published routes and procedures.	Automated air traffic management enables higher density of flights.
Instrument Flight Procedures	Currently utilized procedures.	New procedures required for automated vertical guidance to surface.	UAM flight tracks are designated as UAM corridors managed by automated ATM.
Pilot-in-Command	Onboard pilot.	Multi-vehicle supervisor (Up to three vehicles).	Multi-vehicle supervisor (Many vehicles).
Flow Management and Separation Services	Operators file flight plans. ATC provides separation services.	Operators file high-fidelity flight plans. ATC provides separation services.	Flight planning and separation services are automated within a UAM corridor.
ATC Hand-offs and Check-ins	Pilots engage with ATC via voice communications.	More automated voice communications with ATC.	Communication is automated within a UAM Corridor.
Heliport and Vertiport Surface Control	Heliport operators authorize access to their surfaces. Fixed-base operators (FBOs) manage schedule and coordinate surface movement.	Vertiport managers control surface movement and slot allocations immediately above the vertiport.	Vertiport managers control aircraft movement in vertiport airspace and control surface movement/slot reservation.



Regulatory Engagement

Existing regulations will need to be modified to enable uncrewed UAM operations. Current certification and operations rules may be used when appropriate, but modifications will be needed to address the novel nature of these platforms (e.g., electric distributed propulsion, detect and avoid autonomy, etc.). As industry works to develop consensus standards for these new technologies, regulators will be asked to adopt these standards as acceptable means and methods of compliance.

While UAM aircraft operators will be approved under Part 135 or Part 121, flight operations rules will need to be modified to enable a safe evolution of the airspace for autonomous UAM operations. Ultimately, new flight rules and automated traffic management will eliminate the need for ATC-provided separation services. However, the introduction of supervised aircraft in the mid-term will require rule modifications that retain ATC separation services for instrument flight.

Technical advances in the communications, navigation, surveillance, and information infrastructure currently in deployment will, in both VMC and IMC, enable vertical autonomous landings and a higher flight tempo than IFR procedures can support. This includes the UAM aircraft participating in ATC separation services along new high-precision routes directly connecting the UAM vertiports.

Globally, regulatory changes will be needed to allow the new UAM ecosystem to thrive and grow in a safe manner. Organizations like the International Civil Aviation Organization (ICAO) will play a key role in facilitating and encouraging harmonized rules and operations. In addition, export rules may need to be modified to enable worldwide scalability.

Workforce Engagement

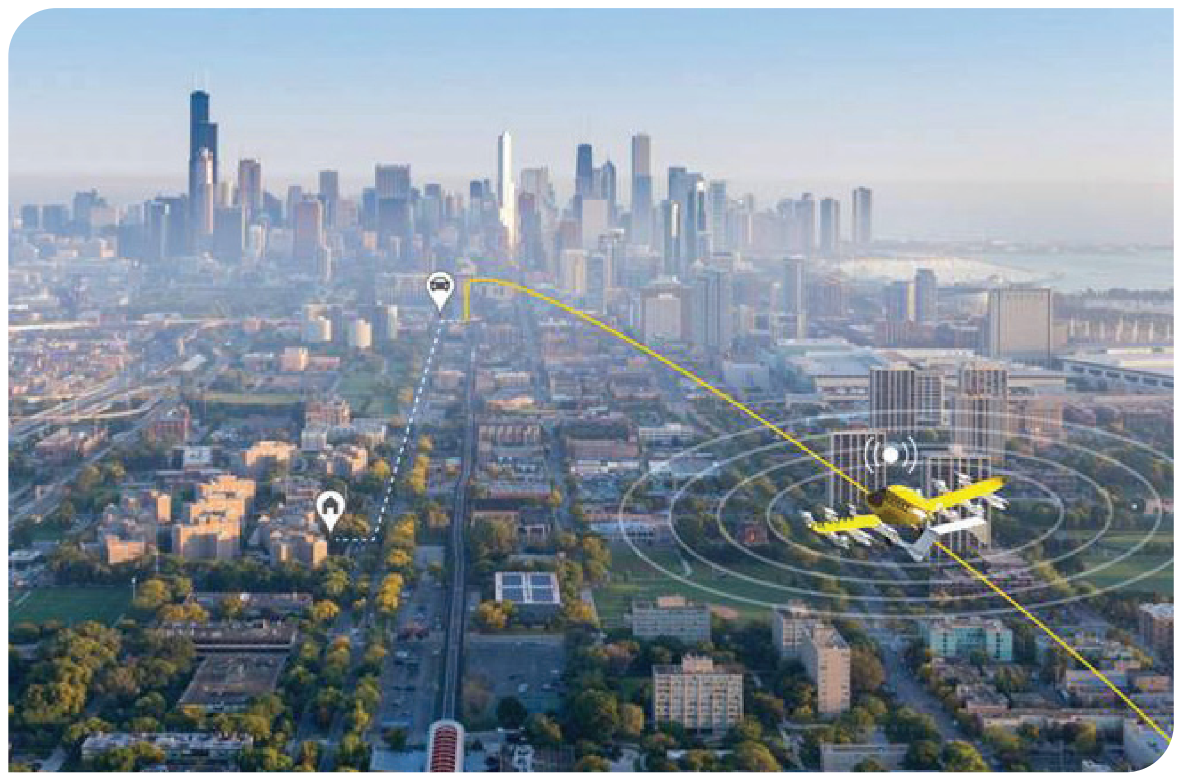
A novel and unique workforce will be required for UAM and the broader AAM industry. New career paths will combine traditional aviation with autonomy and electrical propulsion which have the potential to alleviate anticipated pilot shortages. This will require intentional actions to ensure that the workforce supporting autonomous UAM has the right knowledge and skill sets.

Targeted investment in training and education from both the private and public sectors will be needed to prepare this next generation workforce for UAM and AAM.

Community Engagement

Fostering public acceptance of UAM will be a crucial component to scale the market and justify the business case. The aviation industry will need to build the public's confidence in UAM to confirm the aircrafts are safe, reliable, and economical in terms of time and money.

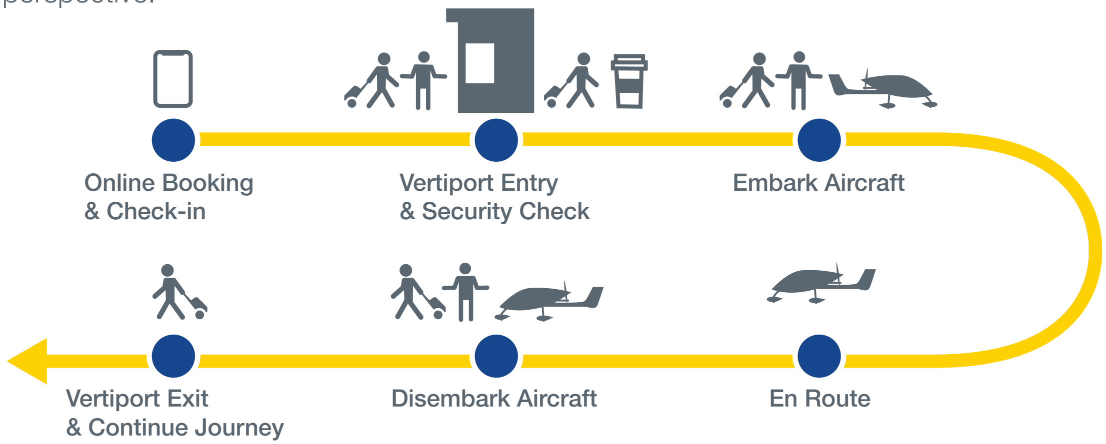
It will be crucial for industry to work with local cities and economic development organizations to effectively evaluate, plan, and implement the changes required to safely integrate UAM in the airspace. Some cities have already developed AAM working groups composed of business, local government, and community organizations to support the community needs of AAM and UAM.



Passenger Journey

This operational vignette illustrates a typical operational day for an uncrewed UAM. Flights will be conducted using standard operating procedures that ensure safe and scalable operations.

The graphic below shows how an operational day would look from the passenger perspective.



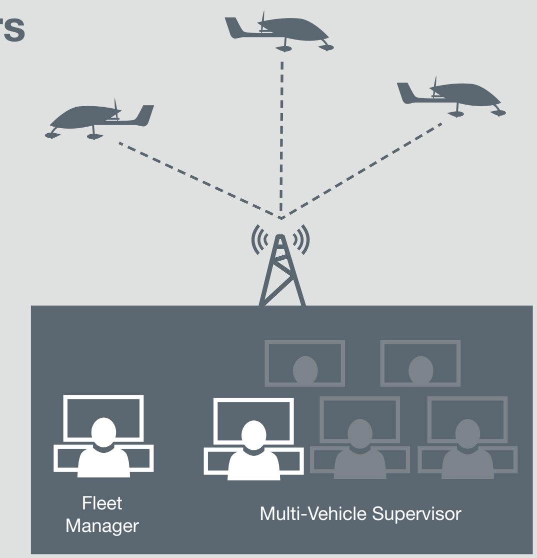
Fleet Operations Centers

Fleet Operations Centers (FOC) are physical facilities that host the personnel responsible for the planning and monitoring of each phase of UAM aircraft operations.

Key personnel located in FOCs will include:

Fleet Manager (FM): Responsible for fleet and resource scheduling

Multi-Vehicle Supervisor (MVS): Responsible for supervising multiple UAM aircraft and fulfilling the legal role of the pilot-in-command



Fleet Operations Center

Key Roles and Responsibilities:

UAM aircraft: UAM aircraft will have autonomous stability and control with automatic flight plan execution and will be capable of executing a complete flight plan, even in the absence of an active C2 datalink. They will be equipped to avoid airborne and ground-based hazards and designed to maintain passenger safety and comfort.

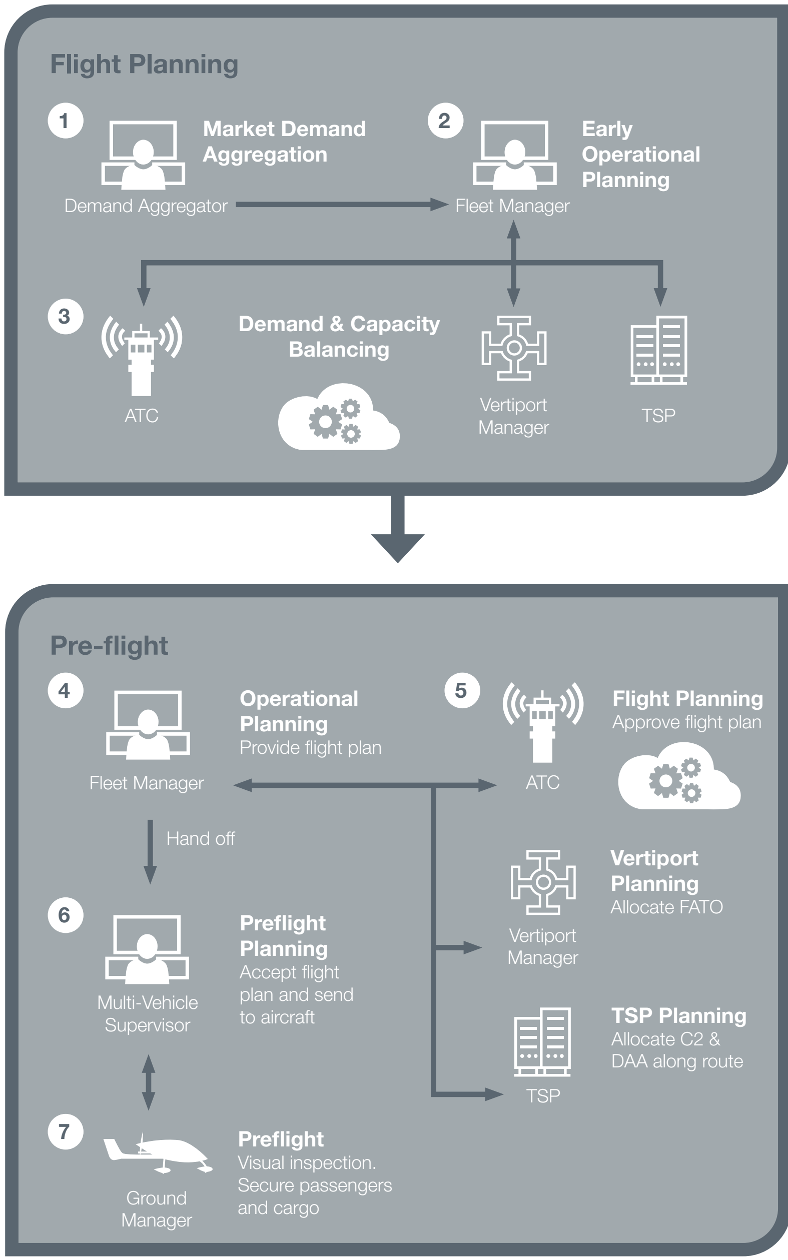
Third-party service providers (TSP): TSPs will provide information, telecommunications, and ground-based solutions to replace key functions that are currently provided by on-board pilots. These functions will include datalinks, aeronautical data services, ground-based detection of conflicting traffic, and other services.

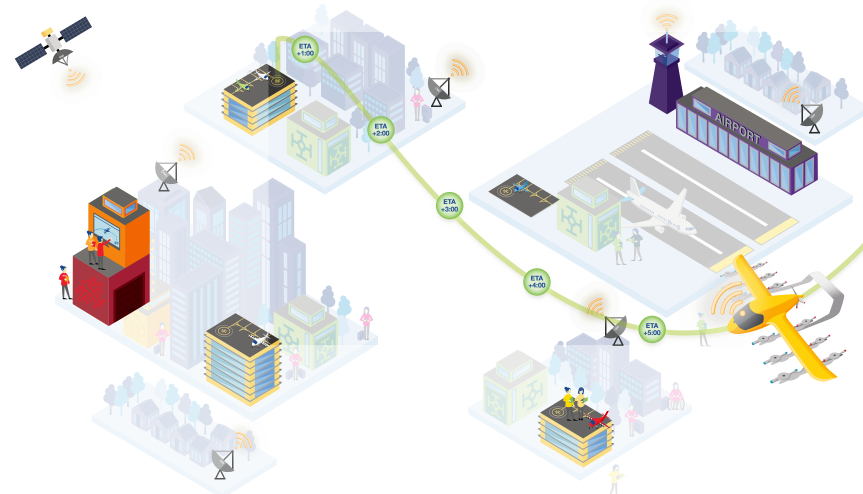
Vertiports and vertiport managers: Vertiports will be fixed locations where UAM aircraft will take off and land, load and unload passengers, and receive services (e.g., energy replenishment). Vertiport managers (VMs) will ensure safe and efficient vertiport usage as well as coordinate surface movement.

Airspace, ATC, and communications, navigation, and surveillance (CNS) infrastructure: While UAM operations will leverage the existing air transportation system to the maximum extent possible, there are areas where evolution will be necessary to enable uncrewed UAM aircraft operations.

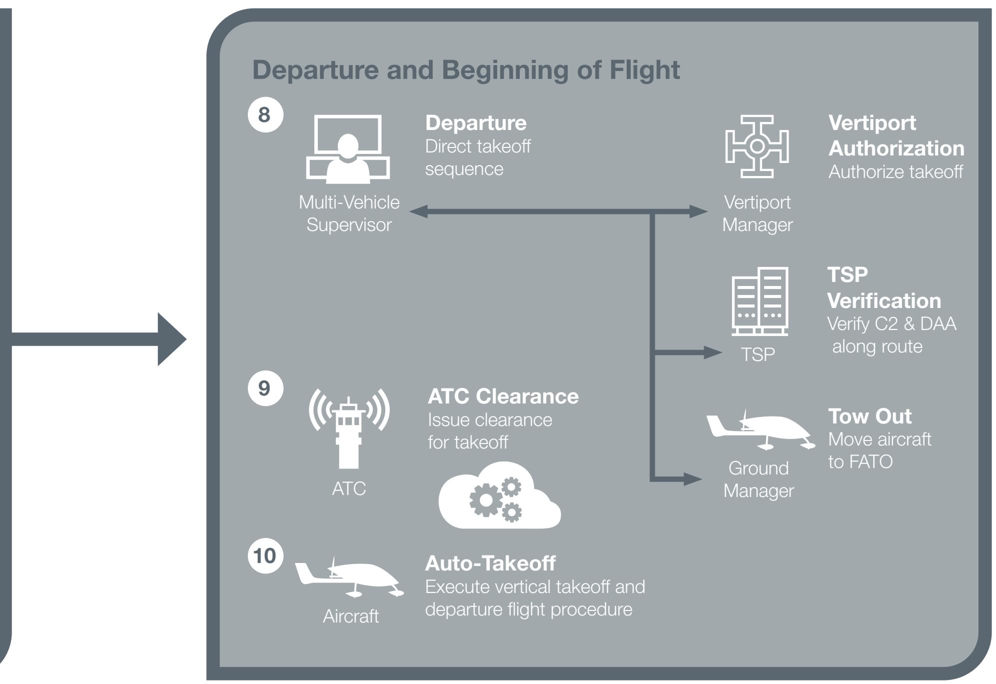
Nominal Operational Activity

The following section illustrates the various operational roles and interactions between those roles for a routine flight. After takeoff, the uncrewed UAM aircraft will navigate along a predefined flight path. The MVS will monitor flights, implement ATC instructions to maintain aircraft separation, and ensure safe execution of the flight.



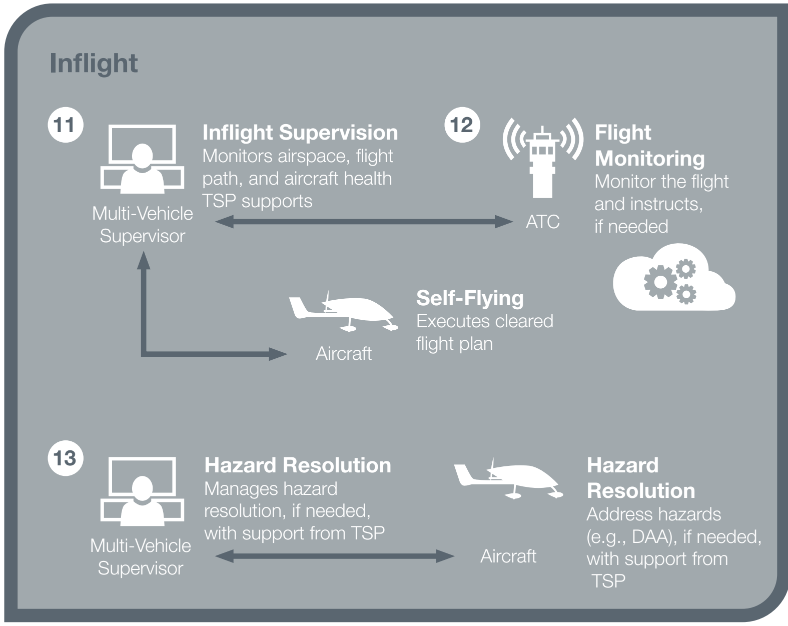


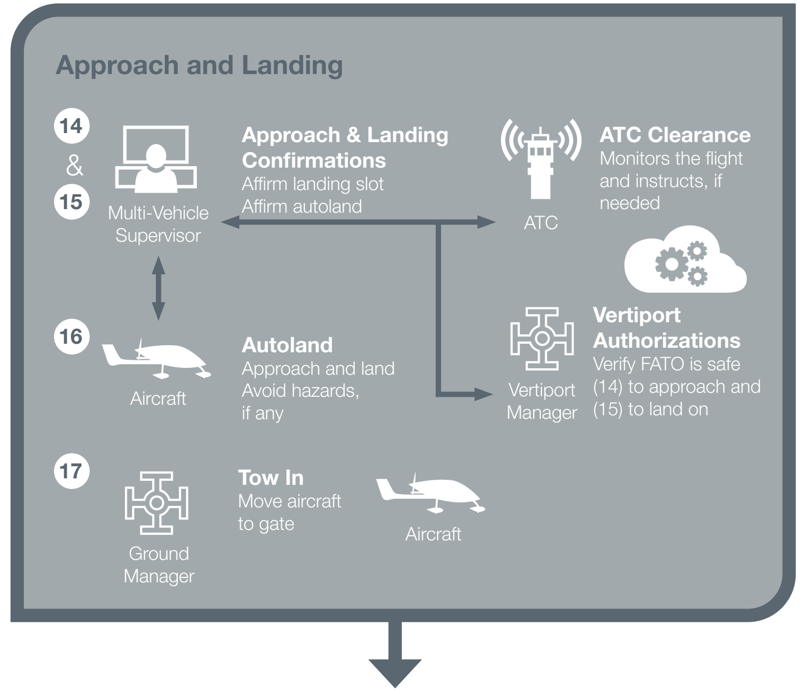
This graphic portrays a nominal flight for the UAM aircraft.

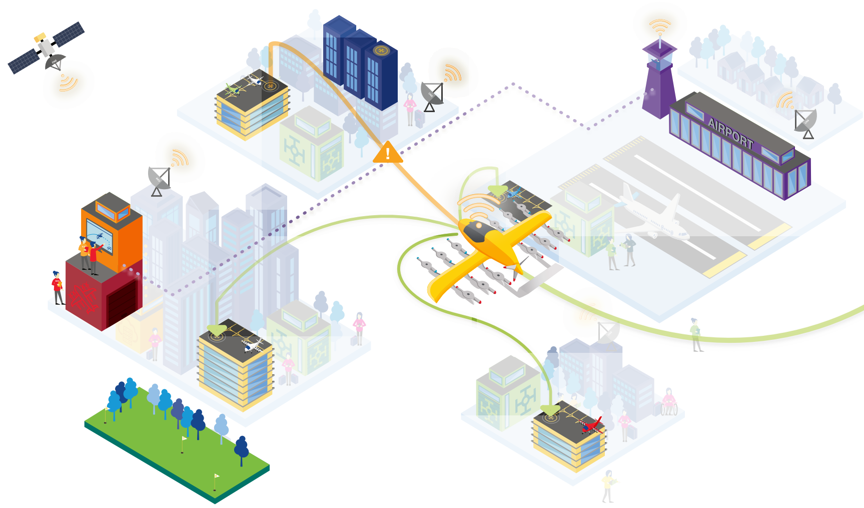


Nominal Operational Activity Continued

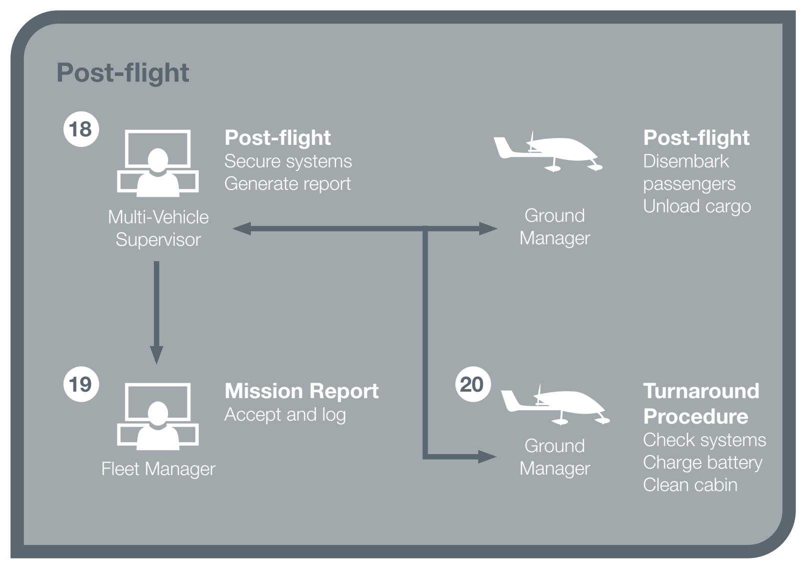
The MVS will coordinate approach and landing operations to ensure it is safe to approach and land. If a UAM aircraft experiences a degraded state, procedures will be in place for the VM's response. The flight plan includes alternate landing site availability to accommodate aircraft diversions as shown in the figure below. Once the landing zone is verified safe, the UAM aircraft will approach and land.







This graphic portrays a diversion procedure due to an anomaly that occurred during flight. The UAM aircraft has found alternative routes and will land when necessary.



For more information
https://www.boeing.com/innovation/con-ops