Concept of Operations for Uncrewed Urban Air Mobility

Summary v2.0

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
CEO of Wisk

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 conops@wisk.aero.

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

*Wisk is a Boeing subsidiary. SkyGrid is a Boeing Joint Venture. Aurora Flight Sciences is a wholly owned Boeing subsidiary.

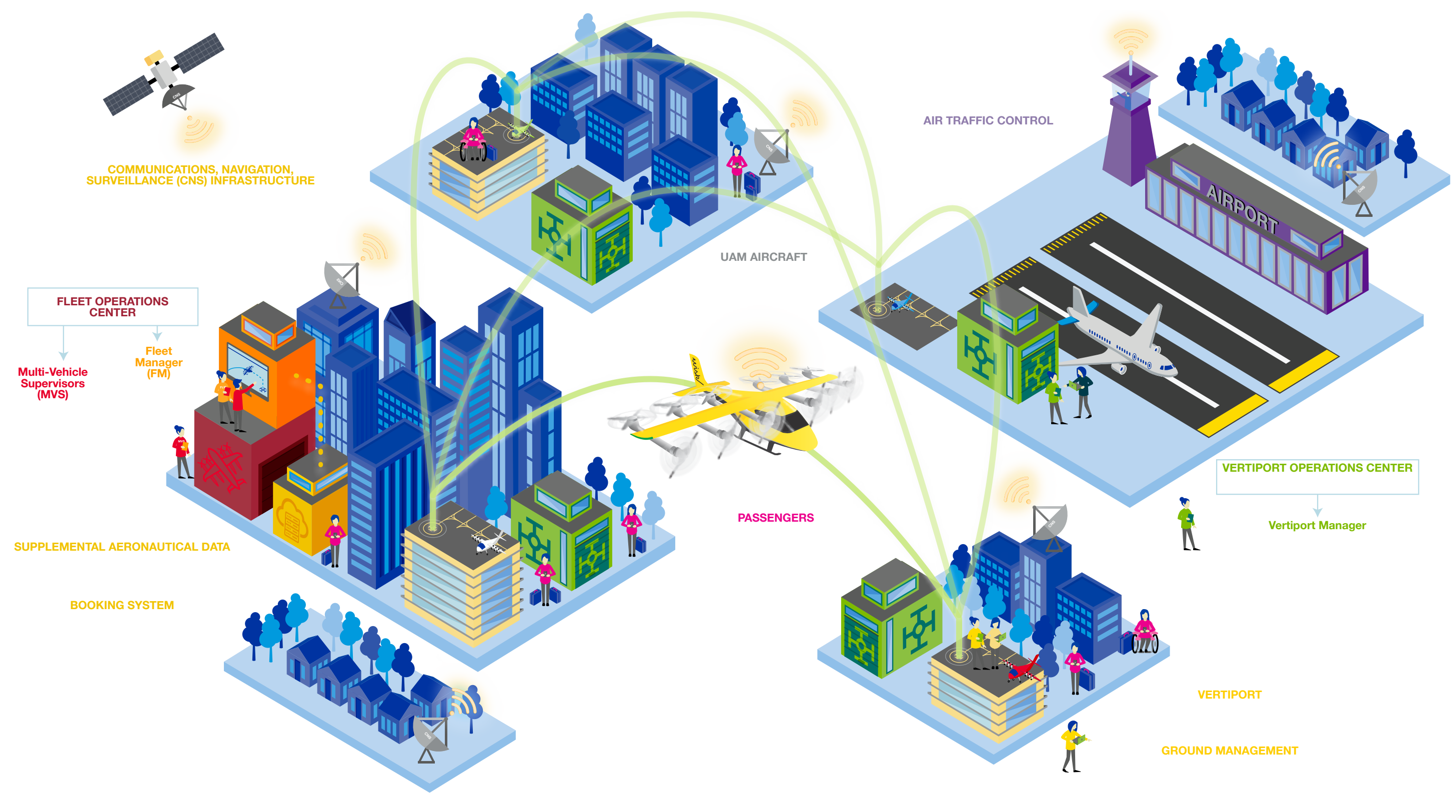
Introduction

The purpose of this document is to provide an update to the Concept of Operations (ConOps) for uncrewed, passenger-carrying, urban air mobility (UAM) operations using highly automated, electric aircraft. This document outlines a high-level vision, in parallel with a detailed document, with technology, regulatory, and social recommendations to help make uncrewed UAM a safe reality.

The updates incorporate industry and government stakeholder feedback and reflect changes to align with most recent publications (ex., FAA UAM ConOps v2.0). This document targets the safe initiation of uncrewed UAM passenger operations in the United States National Airspace System (NAS) by the end of this decade, while providing a stepping stone to the goal of transitioning to high-throughput operations in the years that follow. It describes the key principles and assumptions for UAM aircraft, the operational environment, and normal operations that rely mostly on existing traffic management concepts.

Current certification, airspace, and operating rules will be complied with to the greatest extent possible; however, some modifications will be needed to address the capabilities of new UAM platforms. Globally, regulatory frameworks will need to evolve and be harmonized to enable this new UAM ecosystem and ultimately bring it to a fully scalable mode of transportation benefitting from the technological advances implemented within the aviation industry. Public acceptance of uncrewed UAM operations will be crucial to scaling the market.

Through collaboration, engineering excellence, and a safety mindset, Boeing and Wisk, alongside their respective partners, intend to lead the advancement of the UAM industry to achieve a future state where safe and affordable, everyday flight can be available to 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, CASA	Work to support the safe integration of UAM into the airspace.
Trade Associations	AUVSI, AIA, GAMA, HAI, AOPA	Work with industry to support national competitiveness and to further advance policies.
Standards Development Organizations	RTCA, EUROCAE, ASTM, SAE	Aim to develop industry consensus-based standards to be used as a basis for certification.
UAM Industry	Wisk, SkyGrid, Insitu, Aura, Skyports, Vertical, Joby, Eve, OneSky, etc.	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, Southwest, 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, EuroControl	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

Uncrewed UAM will be the result of enabling technologies such as battery and distributed propulsion advancements, ubiquitous communication and localization capabilities, and advances in automation systems. This convergence will support the adoption of:

- **UAM-centric flight plans:** UAM-centric flight plans will provide flow management for UAM operations on UAM Routes that will enable strategic separation and sequencing and support procedural deconfliction and conformance monitoring.
- **Comprehensive air and ground situational awareness:** Situational awareness will support optimized flight planning in the presence of weather, traffic congestion, airspace, as well as obstacle and terrain constraints.
- **Vertiport automation system:** These systems will streamline vertiport capacity balancing and allocate real-time landing zone availability which will help minimize FAA ATC actions in managing UAM traffic.
- **(C2) link infrastructure:** C2 links will provide reliable and deterministic ground-to-air command and control capabilities.
- **Detect and avoid (DAA) and landing hazard avoidance (LHA) systems:** DAA and LHA systems will provide UAM aircraft with tactical conflict management capabilities.
- **Voice communications:** Reduced voice-based communication, per procedural agreements, will support initial operations. As operational tempo increases, a transition to digital voice communication will begin as part of UAM infrastructure scale-out.

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 mature-state 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.

	Initial UAM	Mid-term UAM (This ConOps)	Mature UAM
Timeframe	Now-2028	2028-2032	2032+
Flight Operations	Visual Flight Rule (VFR) and Instrument Flight Rule (IFR) operations.	VFR and IFR-expanded operations with special flight procedures[1] where UAM aircraft will adhere to published UAM RNP routes and instrument procedures with operator-induced spacing and sequencing.	Automated Flight Operations (AFO) where automated traffic management solutions will enable reduced aircraft separation and higher traffic density.
Airspace (Class B, C, D, E, G[2])	Existing and new routes.	Published UAM RNP routes. Some terminal areas may benefit from point-to-point UAM corridor structures with mandatory ATC participation.	High-density dynamic UAM corridors integrated in terminal airspace.
Instrument Flight Procedures	SIDs, low-altitude routes, IAPs, missed-approach procedures. Visual segments require an onboard pilot to complete flight to the surface.	Published RNP procedures. New procedures and criteria will enable automated vertical guidance from and to the surface.	RNP procedures supported by UAM corridors (enveloped in designated airspace) managed by automated traffic management.
Pilot	Onboard pilot.	MVS (up to three aircraft[3])	MVS (many aircraft).
Flow Management and Separation Services	Operators file flight plans. ATC provides separation services to IFR and some VFR aircraft via VHF voice communications.	Operators will file flight plans supported by TSPs. ATC will provide separation services to UAM aircraft via voice communications. Flight plans, route structures, and between operator coordination practices will minimize the need for separation services.	Flight planning and separation services will be automated for all UAM operations under AFO.
ATC Handoffs and Check-ins	Pilots engage with ATC over VHF voice communications, manually switching frequencies.	Voice communications systems and appropriate Letters of Agreement will support more automated handoffs, check-ins, and link verification with ATC.	VMs will control surface movements and slot reservations. Airspace above vertiports is controlled by automated traffic management to provide greater operational fidelity.
Heliport and Vertiport Surface Control	Heliport operators authorize access to their surfaces. Fixed-base operators (FBO) manage schedules, coordinate surface movements.	VMs will control surface movements and slot reservations. Slot allocations will procedurally regulate access to airspace immediately above vertiport FATOs.	RNP procedures supported by UAM corridors (enveloped in designated airspace) managed by automated traffic management.

[1] UAM operations will leverage Letters of Agreement, as well as waivers, exemptions, and special procedures (where necessary) for support of integration into the NAS, as outlined by the Special Procedures and Airspace FAA Group in accordance with the FAA Order 8260.60.
[2] Passage through uncontrolled airspace (i.e., Class G) will usually occur only during approach and departure flight segments.
[3] Given that multi-vehicle supervision is not part of the legacy VFR and IFR paradigms, the integrated UAM systems are being designed from the start to enable it. In this Midterm ConOps, the operational implementation of aircraft-to-supervisor ratio will be context specific (i.e., at 1:1, 1:2, 1:3, etc.) depending on the operational specifications, human factors studies, regulator's approvals, and aviation safety limitations.

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 propulsion, DAA, autonomy, etc.). In addition to the development of industry standards for these new technologies, regulators will need to adopt these standards and develop the means and methods of compliance.

While UAM aircraft operators will be approved under 14 CFR Part 135 or Part 121, flight operations will need to cater to a safe evolution of the airspace for autonomous UAM operations. While new flight rules and automated traffic management would eliminate the need for ATC-provided separation services, in this document, 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.

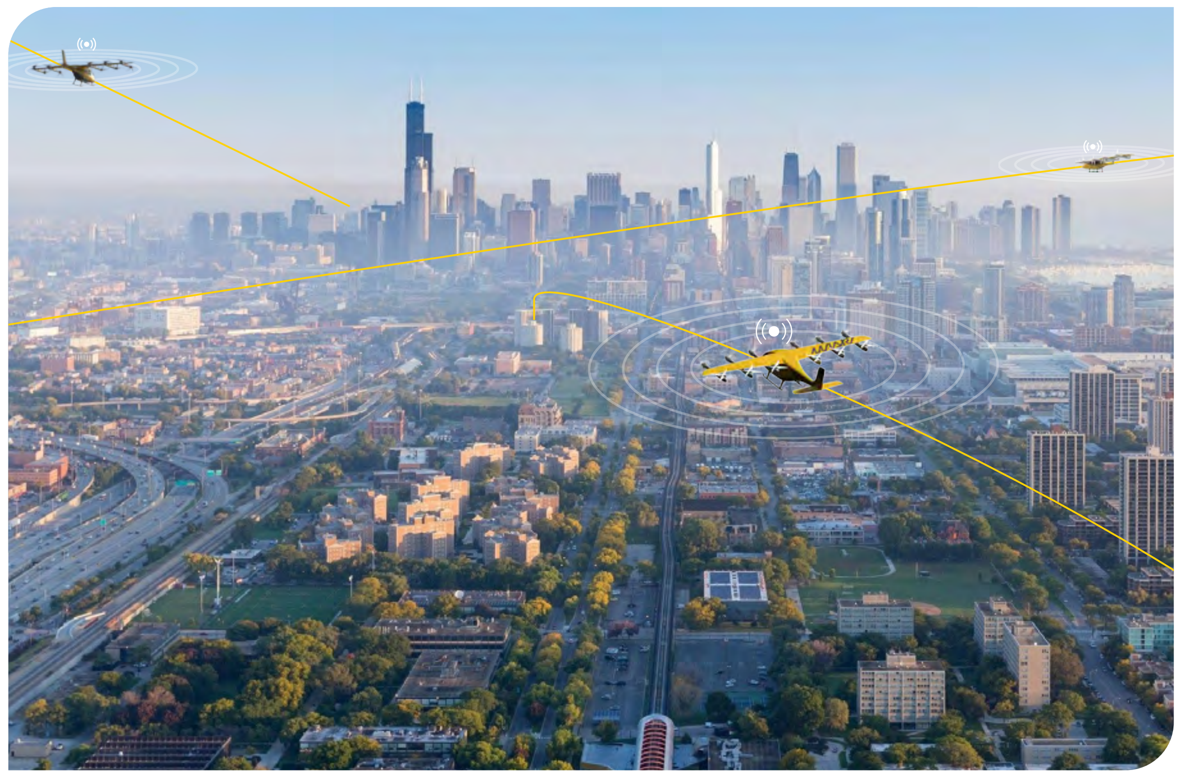
Workforce Engagement

A novel and unique workforce will be required to support UAM operations. This new workforce will need both traditional aviation skills as well as the knowledge and skills that will be required to support highly automated, electric UAM aircraft. The public and private sectors will need to take intentional actions and make targeted investments to educate and train this next generation workforce

Community Engagement

Fostering public acceptance of UAM will be a crucial component to scale the market and justify the business case. The public will need to be convinced that traveling on UAM aircraft will be safe, reliable, and save them time and money.

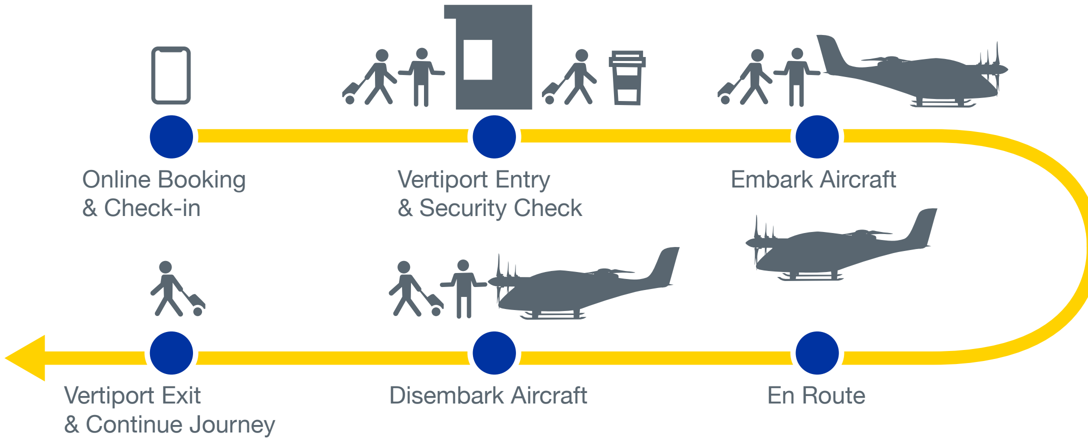
It will be crucial for industry to work with local cities and economic development organizations to effectively evaluate, plan, and implement the changes required to safely integrate UAM in the airspace. Some cities have already developed AAM working groups composed of business, local government and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



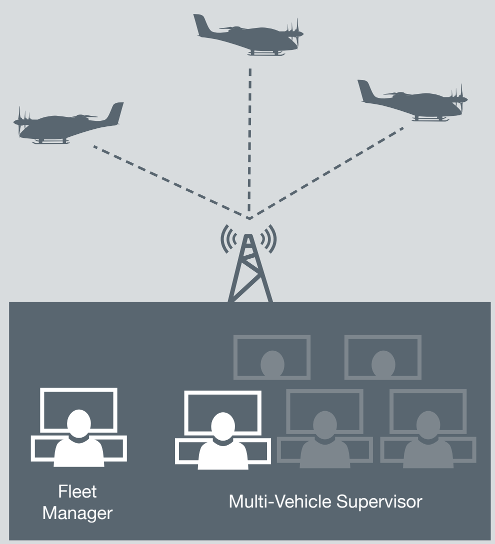
Fleet Operations Centers

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 supported by aircraft and workstation automation as part of the human-machine teaming FOC concept.



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 hazards and terrain and designed to maintain passenger safety and comfort.

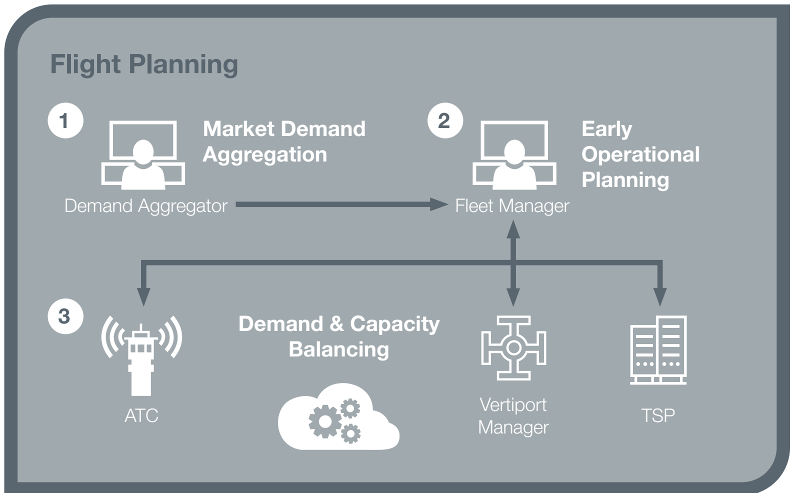
Third-party service providers (TSP): TSPs will provide information, telecommunications, and ground-based solutions to replace key functions that are currently provided by on-board pilots. These functions will include datalinks, aeronautical data services, ground-based detection of conflicting traffic,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

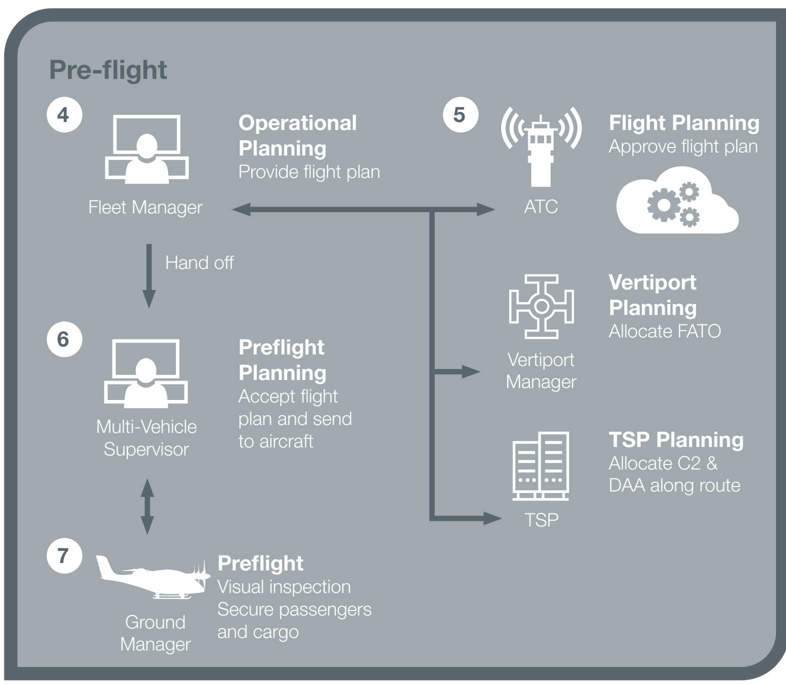
Airspace, ATC, and communications, navigation, and surveillance (CNS) infrastructure: While UAM operations will leverage the existing system to the maximum extent possible, uncrewed UAM operations will be further enabled via specific procedures and routes that will require minimal ATC interactions.

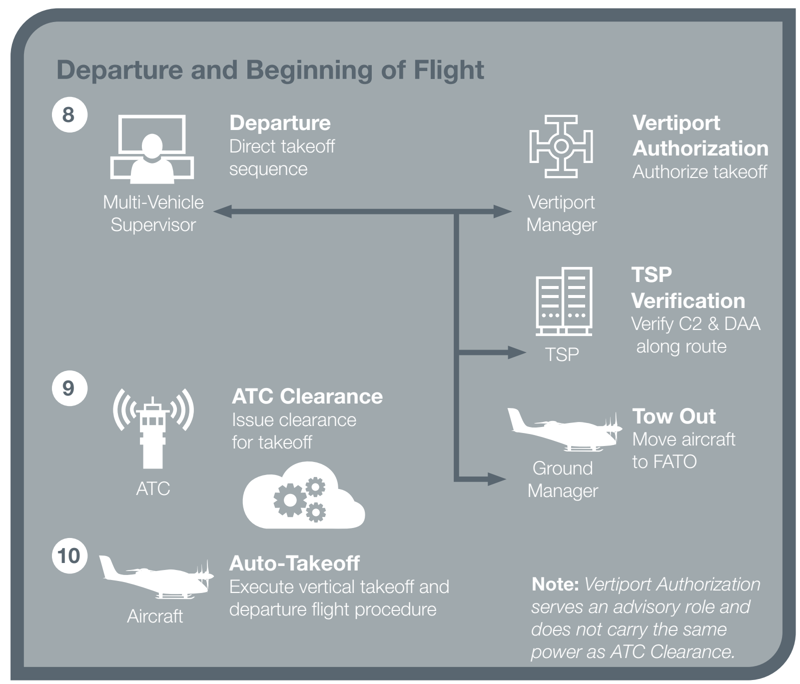
Nominal Operational Activity

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.

Inflight

11 Multi-Vehicle Supervisor — **Inflight Supervision**
Monitors airspace, flight path, and aircraft health
TSP supports

12 ATC — **Flight Monitoring**
Monitor the flight and instructs, if needed

Aircraft — **Self-Flying**
Executes cleared flight plan

13 Multi-Vehicle Supervisor — **Hazard Resolution**
Manages hazard resolution, if needed, with support from TSP

Aircraft — **Hazard Resolution**
Address hazards (e.g., DAA), if needed, with support from TSP

Approach and Landing

14 & 15 Multi-Vehicle Supervisor — **Approach & Landing Confirmations**
Affirm landing slot
Affirm autoland

ATC — **ATC Clearance**
Monitors the flight and instructs, if needed

16 Aircraft — **Autoland**
Approach and land
Avoid hazards, if any

Vertiport Manager — **Vertiport Authorizations**
Verify FATO is safe (14) to approach and (15) to land on

17 Ground Manager — **Tow In**
Move aircraft to gate
Aircraft

Post-flight

18 Multi-Vehicle Supervisor — **Post-flight**
Secure systems
Generate report

Ground Manager — **Post-flight**
Disembark passengers
Unload cargo

19 Fleet Manager — **Mission Report**
Accept and log

20 Ground Manager — **Turnaround Procedure**
Check systems
Charge battery
Clean cabin

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.wisk.aero/conops