Concept of Operations for Uncrewed Urban Air Mobility

Version 2.0

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 that integrates them into the airspace, 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.[1] 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

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[1] SkyGrid is a Boeing joint venture. Wisk and Aurora Flight Sciences are wholly owned Boeing subsidiaries.

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Executive Summary

This document is a second iteration of a Concept of Operations (ConOps) for uncrewed,[2] passenger-carrying, urban air mobility (UAM)[3] operations using highly automated, electric aircraft. The document incorporates industry and government stakeholder feedback and reflects changes to align with most recent publications (ex., FAA UAM ConOps v2.0[4]). From the implementation standpoint, the main difference between initial publication and this document is a transition from end-to-end trajectory-based operations to procedural methodology of UAM integration into the NAS that doesn't require changes to existing Air Traffic Management (ATM) systems.

The purpose of this ConOps is to provide a potential blueprint for global UAM operations. The ConOps targets safe initiation of uncrewed UAM passenger operations in the NAS by the end of this decade, while providing a steppingstone to the goal of transitioning to high-throughput operations in the years that follow.

UAM operations will be conducted day and night in visual and instrument meteorological conditions (i.e., VMC and IMC). The aircraft will utilize electric propulsion and employ a combination of onboard and ground-based systems to carry out functions currently executed by onboard pilots. Electric propulsion will eliminate direct carbon emissions, reduce noise, and reduce energy consumption. Uncrewed operations monitored and managed by multi-vehicle supervisors, in collaboration with automated systems, will reduce the cost of flight, thereby increasing access and affordability.

This ConOps describes the key principles and assumptions for UAM aircraft, the operational environment, and normal operations that rely mostly on existing traffic management concepts. Fleet operation centers will be physical facilities that host UAM aircraft operator personnel. Third-party service providers will provide capabilities to support remotely supervised flight operations. Vertiports are managed by vertiport operators and are fixed locations where UAM aircraft will take off and land, load and unload passengers, and receive services (e.g., battery charging). Vertiport managers will ensure safe and efficient vertiport usage and coordination of surface movement.

While current certification, airspace, and operating rules will be complied with to the greatest extent possible, modifications will be needed to address the capabilities of new UAM platforms (e.g., electric distributed propulsion, detect and avoid, autonomy, non-visual approach and departure procedures, etc.). 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. The UAM industry will need to work with states, cities, and economic development organizations to effectively evaluate, plan, and implement the changes that will be required to integrate UAM safely and seamlessly into the airspace and ground infrastructure. Ultimately, public acceptance of uncrewed UAM operations will be crucial to scaling the market.

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[2] Uncrewed aircraft are aircraft without an onboard crew.

[3] UAM is a subset of Advanced Air Mobility and focuses on lower-altitude operations within urban environments.

[4] FAA UAM Concept of Operations v2.0 - https://www.faa.gov/air-taxis/uam_blueprint

This iteration of Uncrewed UAM ConOps not only intentionally defines a future that will require an evolution from the current state but also provides a detailed roadmap on the evolutionary steps that must take place to achieve the scalable vision. While UAM aircraft will be designed to support this ConOps, they should be provisioned for the industry's vision of future operations. Using Safety Management System principles, industry must work closely with regulators to reach the proposed midterm state as a steppingstone to the mature state.

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.*

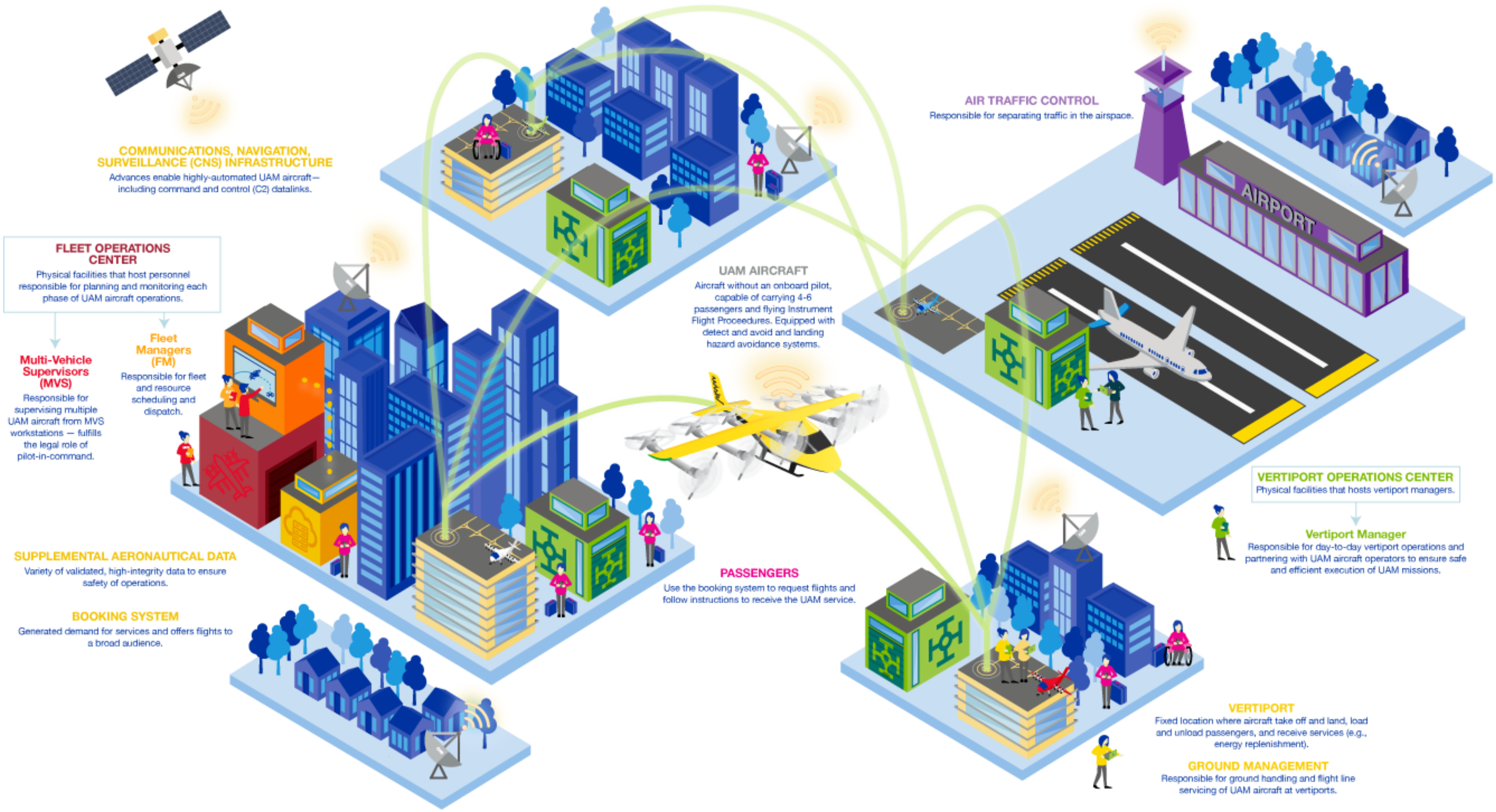

Figure 1. A Concept for Advanced Air Mobility in Urban Environments

1 Introduction

As part of the ongoing collaboration between Wisk and Boeing, this document continues to mature the Concept of Operations (ConOps) for uncrewed, passenger carrying, urban air mobility (UAM) operations involving highly automated, electric aircraft. This concept is presented within the context of the United States national airspace system (NAS) with the intention of conveying a blueprint for operations on a global scale. This ConOps is intended to facilitate stakeholder engagement, concept maturation, and, ultimately, industry consensus on how to enable such operations.

1.1 Purpose

This ConOps v2.0 describes how uncrewed UAM operations can be safely integrated into the NAS by the end of the decade, as well as convey a pathway for scalable industry growth through the advancement of concepts that will create a foundation for Automated Flight Operations (AFO).

1.2 Intended Audience

The intended audience for this document is key public and private stakeholders, including:

- The Federal Aviation Administration.
- The National Aeronautics and Space Administration.
- Current users of the national airspace system (e.g., general aviation, business aviation, airlines, etc.).
- Standards development organizations (e.g., RTCA, ASTM, SAE, EUROCAE, etc.).
- Participants and stakeholders in the UAM ecosystem.
- UAM aircraft original equipment manufacturers.
- Federal, state, and local policy makers.

1.3 Scope

This ConOps focuses on four central elements of UAM operations, namely:

1. **UAM system:** UAM aircraft and the associated ground-based operational control elements.

2. **Operational environment:** The airspace environment, air traffic management system, vertiport environment, regulatory flight rules, and operational procedures.

3. **Normal operations:** A description of standard UAM operations.

4. **Contingency and emergency operations:** Identification of contingency and emergency procedures that will be unique to UAM operations.

1.4 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 Required Navigation Performance (RNP) 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 systems:** 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. These Internet Protocol-based communications will enable constant communication integrity monitoring between ATC operational centers and fleet operational centers, as well as automated transfer capability as UAM aircraft cross ATC facility boundaries.[5]

[5] Similar to intra-facility automated handoffs in STARS, ERAM, or MEARTS in Fused Display Mode.

2 Principles and Assumptions

The key principles and assumptions in this ConOps are based on the overarching goal of providing *safe, affordable, everyday flight for everyone*.

- **Safe:** UAM operations will meet or exceed the highest safety standards of current commercial aviation.
- **Affordable:** Remote supervision will eliminate the weight and cost of flight crews. Electric propulsion will reduce fuel and maintenance costs. These reductions will allow UAM operators to provide affordable flight for everyone.
- **Everyday flight:** Day and night operations in visual meteorological conditions (VMC) and instrument meteorological conditions (IMC) will be possible. Electric propulsion will minimize aircraft noise and eliminate direct carbon emissions.

2.1 Automation Levels

Autonomy-related terms, as used in this ConOps, are defined as follows:

- **Human-within-the-Loop (HWTL):** systems will follow pre-defined, finite, and thus predictable, deterministic sequences of tasks. A system may be interrupted by operators and will require human initiation and direct supervision.
- **Human-on-the-Loop (HOTL):** systems will select from a pre-defined, finite set of tasks to achieve a given objective or regulate subsystems *conditionally*, but *without the need for direct supervision. HOTL* systems *may* involve human intervention.
- **Human-over-the-Loop (HOVTL)**: systems will independently decide their own course of tasks to achieve a given objective without the possibility of human intervention.

Key principles that will govern UAM aircraft system design relate to these behaviors:

- **HOVTL stability control:** Without an onboard pilot, UAM aircraft will *autonomously* manage the stability and inner loop control of the vehicle and will not be piloted remotely.
- **HOTL contingency and emergency behaviors:** UAM aircraft automation with human supervision will manage navigation during contingency and emergency scenarios. This may include selecting the best emergency landing zone (ELZ) based on an aircraft's energy state, information on potential zones, and other behaviors.
- **HWTL navigation behaviors:** UAM aircraft will automatically execute flight plans along defined UAM RNP routes.

2.2 Urban Air Mobility Aircraft System

This ConOps defines the UAM aircraft system to be composed of the UAM uncrewed eVTOL vehicles and the complementary ground facilities that will be tightly integrated into the vehicle operation. The ground facilities will provide not only the usual airline fleet operations management and flight dispatch functions, but also some essential functions currently performed by onboard pilots that will be allocated by design to automation and personnel on the ground.

2.2.1 System

The following list of assumptions is driven by the principles in section 2.1 regarding the UAM system:

- **Operational behaviors:** Whenever possible, UAM aircraft will follow the guidance, best practices, and recommended procedures currently used in the air transportation system.
- **C2 datalinks:** UAM aircraft will be equipped with a C2 datalink that will connect the aircraft to a fleet operations center (FOC) on the ground. If the C2 datalink is interrupted, UAM aircraft will enter a predetermined lost-link operational state,[6] which will trigger specific lost-link contingency procedures (e.g., squawk 7400 and proceed according to the approved flight plan).
- **Cybersecurity:** UAM aircraft and associated systems will require strong cybersecurity for protection and resilience against intentional and unintentional cyberattacks.
- **Operator certificated:** UAM aircraft operators will be certified under 14 CFR Part 135 or Part 121.

2.2.2 Aircraft

The following list of assumptions is driven by the principles in section 2.1 regarding the UAM aircraft:

- **Hazard detection and avoidance:** UAM aircraft will be equipped to detect operational hazards (e.g., traffic, weather, terrain, obstacles, etc.), and execute avoidance maneuvers if appropriate. Supervisory oversight and intervention will be possible but will not be required. UAM aircraft will be operated in accordance with applicable collision avoidance, remain well clear, and right-of-way frameworks and regulations.[7]

[6] RTCA's SC-228 has defined equipment requirements for C2 datalinks (see TSO-C213, DO-362 and DO-377A, or later).

[7] These regulations (e.g., 91.113) were written with the assumption of an onboard pilot. RTCA's SC-228 has defined operational and equipment requirements for how aircraft without an onboard pilot can comply with these regulations (see TSO-C211, Detect and Avoid (DAA) Systems, TSO-C212, Air-to-Air Radar (ATAR) for Traffic Surveillance, DO-365B, or later).

- **Precision takeoff and landing:** UAM aircraft automation will enable vehicles to take off and land without the need for a visual segment.
- **Avionics equipment:** UAM aircraft will have autoflight and communications, navigation, and surveillance (CNS) capabilities that will meet the performance-based requirements for the airspaces in which they will operate.
- **Type certificate:** UAM aircraft will meet the applicable regulator-defined airworthiness certification requirements.

2.2.3 Supervisor

Uncrewed UAM aircraft will be managed by supervisors located in the FOCs. Each aircraft supervisor will be responsible for monitoring assigned aircraft but will not function as a remote pilot, as the piloting functions will be automated (onboard and in the FOCs). Also, each aircraft supervisor will manage multiple aircraft and be referred to as a multi-vehicle supervisor (MVS).

The following key principles will apply to MVSs:

- **Supervisory in nature**: Under the supervision of an MVS, the avionics suite onboard UAM aircraft automation will execute the flight.
- **Authority over automation**: MVSs will be able to override flight intent of the UAM aircraft unless an aircraft has lost its C2 link.

The following key assumptions apply to MVSs and MVS stations:

- **Multi-vehicle supervision:** MVSs will have responsibility for as many as three UAM aircraft. As the UAM ecosystem advances further, though, they are expected to have authority for more than three aircraft in the mature state.
- **Awareness of operational environment**: MVS stations will provide the information necessary to ensure sufficient operational awareness (e.g., aircraft limitations, airspace constraints, etc.).
- **Hazard avoidance:** Both before and during flight, MVSs will be responsible for verifying flight plans and their associated trajectories to avoid hazardous conditions (e.g., traffic, weather, terrain, obstacles, etc.). MVSs will be able to modify aircraft flight path based on the options in the route database if they determine that the aircraft will encounter a hazard on the current route.
- **Two-way communications with ATC:** MVSs will be responsible for establishing and maintaining two-way voice communications with ATC as required by the operation, airspace, and agreements with ATC (e.g., Letters of Agreement with respective ATC facilities). Automation of basic communication functions will streamline the activities of the MVSs.
- **Interaction among multiple MVSs:** Depending on the operational practices of the operator and aircraft capabilities, specific procedures regarding how MVSs will hand off aircraft (e.g., during shift changes) may be established upon approval from respective regulators.
- **Off-nominal procedures:** If a UAM aircraft experiences an emergency or contingency that requires the focused attention of a single MVS, procedures for handing off the other aircraft under the MVS's supervision may be leveraged.

2.3 Airspace and Air Traffic Management

Key principles for the integration of UAM aircraft into today's airspace and transportation system are:

- **Existing infrastructure:** Maximizing the use of the infrastructure, procedures, and services provided by the existing air transportation system.
- **Enabling regulation:** New and revised regulations and operational policies will enable new operations and their integration into the NAS.
- **High-fidelity flight planning:** UAM operations will entail high levels of efficiency and predictability that will be attained by conformance to detailed flight plans with both spatial and time elements.
- **Minimal conflicting traffic:** Collaborative flight planning will enforce limits on traffic flow demand and will avoid intersecting flight paths. Flight plans will be end-to-end, from takeoff to landing, and will be approved and routinely executed in their entirety.

Key assumptions for the integration of UAM aircraft into today's airspace and transportation system are:

- **Airspace classes:** UAM aircraft will depart from, operate in, and land at locations in the G, E, D, C, and B airspace classes.
- **Instrument procedures:** UAM operations will leverage published UAM RNP routes and instrument flight procedures (IFP)—including low-altitude airways; instrument approach procedures (IAP), including missed approach procedures and transitions; and standard instrument departures (SID) with departure transitions.
- **RNP authorization required (AR):** UAM aircraft and multi-vehicle supervisory systems will be equipped and approved to follow RNP AR approaches and departures.
- **Vertical segments:** UAM aircraft operations will use IFPs that provide vertical guidance to and from surfaces. Avionics, autoflight automation, and SIDs and IAPs will be created to accommodate the vertical takeoff and landing segments associated with final approach and takeoff (FATO) areas.
- **Dedicated UAM RNP routes:** Although dedicated airspace may not be required, dedicated UAM RNP routes would contribute to operational efficiency gains and would reduce ATC interventions to resolve traffic conflicts. By design, UAM RNP routes will not interfere with other published routes and airspaces, and thus will provide some procedural separation.
- **Clearances:** UAM operations will obtain IFR clearances from respective ATC facilities following standard procedures for respective controlled or uncontrolled airports.

2.4 Third-Party Service Provider

Third-Party Service Provider solutions that will replace key functions currently performed by an onboard pilot will be provided by a third-party service provider (TSP), an entity separate from the UAM operators and ATC. The following key principles will apply to TSPs and their services:

- **Secure:** Cybersecurity will be a key design requirement given the distributed nature of TSP systems.
- **Data and functions:** TSPs will provide databases as well as information products based on those databases. For example, a TSP may provide a database of Notices to Airmen (NOTAM) but might also provide optimized flight paths that consider the limitations imposed by those NOTAMs.

Key assumptions regarding the services TSPs will provide include:

- **Traffic awareness:** TSPs will provide low-latency data to FOCs for traffic awareness, similar to SWIM data. Data and underlying services will form a foundation for TSP separation service capabilities necessary for enabling higher UAM density operations.
- **Weather awareness:** UAM operators will use weather data provided by TSPs to avoid flight in hazardous weather and to address challenges unique to UAM aircraft operations, such as peculiar weather in complex low-altitude environments and highly dynamic wind variability.
- **C2 datalinks:** TSPs will implement and maintain the C2 datalink infrastructure required for UAM aircraft operations. This infrastructure will provide deterministic and predictable C2 link coverage.
- **Validated aeronautical data:** TSPs will provide the validated databases and real-time data products necessary for flight planning, instrument flight procedure execution, vertiport availability status, etc.

TSP services will gain maturity and gradually take on increased airspace responsibilities - including strategic deconfliction and separation management functions. These increased safety-of-life approved capabilities will initially operate in “shadow-mode” and be assistive during the midterm phase (this ConOps), providing supplemental services to the UAM operators, and transition into “responsible-mode” during the mature UAM phase once operational efficiency, level of safety, and public acceptance exist.

2.5 Vertiport Manager

At each vertiport, the following key principles will apply to vertiport managers (VM):

- **Resource assurance:** VMs will provide resource assurance for operator reservations (e.g., FATO reservations). These assurances will be needed for eVTOL aircraft because they will have limited capabilities for hovering and re-routing due to their all-electric design.
- **Local surface control authority:** VMs will maintain authority over the surfaces that they control. Authority over the airspace will remain with ATC.

The following key assumptions apply to vertiports:

- **Awareness of vertiport environment:** VMs will provide the information required to ensure sufficient operational awareness for planning purposes and real-time intervention, if needed.
- **Off-nominal procedures:** If a UAM aircraft experiences a degraded state and the contingency or emergency requires the attention of a VM, procedures will be in place for the VM's response. This will also include planning constraints on resource scheduling (e.g., FATO reservations) to accommodate aircraft diversions.

2.6 Establishing a Steppingstone to Urban Air Mobility

UAM aircraft will be engineered to support the ConOps described in this document, while also being provisioned for the industry's vision of future operations. Industry must use Safety Management System principles and work with regulators on operational testing to reach the proposed midterm and mature states.

Table 1 compares the key principles and assumptions of this section with the state of current regulations as well as a mature UAM ConOps.

Table 1. Comparison of Current State and Future State for UAM Operations

	Initial UAM	Midterm 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[8] 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[9])	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[10]).	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.	Communication integrity checks will be automated or eliminated within the UAM corridor environment.

[8] 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.

[9] Passage through uncontrolled airspace (i.e., Class G) will usually occur only during approach and departure flight segments.

[10] 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.

	Initial UAM	Midterm UAM (This ConOps)	Mature UAM
Heliport and Vertiport Surface Control	Heliport operators authorize access to their surfaces. Fixed-base operators (FBO) manage schedules and coordinate surface movements.	VMs will control surface movements and slot reservations. Slot allocations will procedurally regulate access to airspace immediately above vertiport FATOs.	VMs will control surface movements and slot reservations. Airspace above vertiports is controlled by automated traffic management to provide greater operational fidelity.

The remainder of this document describes operations as envisioned in the Midterm column in Table 1. It is important to acknowledge that the concepts and principles of the autonomous UAM operation, as outlined in this ConOps, require successful demonstration that the safety of all aircraft in the environment is maintained throughout all phases of flight and in nominal, contingency, and emergency scenarios.

3 Urban Air Mobility System: Aircraft and Fleet Operations Centers

In this ConOps, UAM aircraft are defined as aircraft without an onboard pilot that are capable of carrying 4-6 passengers over distances that typically span 30 to 60 nautical miles. A normal mission profile will involve cruise segments at speeds of 110-120 knots between 1,200 feet to 4,000 feet above ground level (AGL). For UAM aircraft categorized as powered lift, there will be a segment where lift will transition from thrust-borne to wing-borne flight.

3.1 Urban Air Mobility Aircraft

This section describes the equipment that will be necessary to meet flight route and airspace requirements.

3.1.1 Navigation

UAM aircraft will be authorized for RNP AR. They will be able to leverage existing approaches as well as newly designed procedures that will be unique to UAM operations. Leveraging existing approaches and using newly designed procedures will allow UAM aircraft to operate from a large set of vertiports. These procedures will also enable navigation and guidance in consideration of obstacle clearances (laterally and vertically) to the point of transition to vertical autoland.[11] UAM aircraft will have navigation databases that provide navigation information and published procedures (e.g., geospatial information, route information, digital vertiport maps, etc.). These databases will be updated periodically and maintained to ensure integrity.

In case of a failure of a position source or a Global Navigation Satellite System (GNSS) system outage, a redundant, multi-source positioning solution (e.g., a tightly coupled Inertial Navigation System) will be necessary to ensure the safety of UAM aircraft. Contingency procedures for partial failures of positioning or navigation systems will be designed to ensure safe completion of flights.

Most of the current instrument flight procedures contain a visual segment when arriving or departing. For UAM aircraft, new procedures that provide vertical guidance from and to the surface, along with a high-accuracy, integrity, and availability positioning system for departure and landing at designated vertiports will be required.[12] Figure 2 shows how aircraft will use time-based metering along the normal flight path.

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[11] Guidance and navigation to the surface for the autoland function is conceptually similar to an Instrument Landing System CAT III.

[12] See section 4.3.4 for additional discussion on ground-based equipment for precision landing systems.

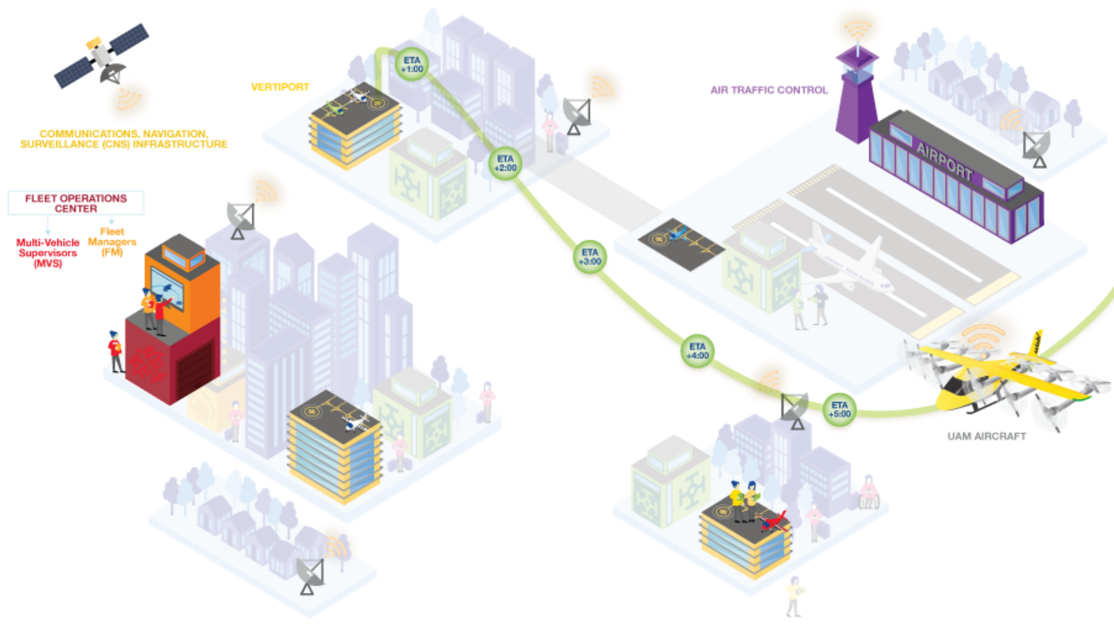

Figure 2. Time-Based Metering along Normal Flight Path

Route selection, design, and execution will be important to electric aircraft due to their limited onboard energy storage capacity. This limitation will require efficient routes that maintain safe landing options along their flight path in the event of a contingency or emergency. Preflight planning, along with real-time monitoring of winds, can ensure that the vehicle's energy state will be sufficient to reach available alternative vertiports, including secure ELZs, if needed. Onboard functions will maintain the best alternative options based on these data to execute a descent and landing if necessary.

3.1.2 Mission Management

UAM aircraft will be equipped with an onboard flight operations management system that will have primary responsibility for the safe execution of flight. This system will be composed of a mission management system (MMS) and vehicle management system (VMS).

MMSs will be responsible for flight plan management and execution, C2, ATC communications, aircraft flight, recording, and maintenance data capture. Any modifications to flight missions will be executed through an interface to the MMS. MMSs will have some overlap (namely flight plan management) with current flight management systems, but they will also have key differences regarding their mission management roles. MMSs will contain sets of predefined IFPs and routes and high-fidelity databases of obstacles and terrain to support safe HOTL navigation.

MMSs will translate flight planning data into commands for VMSs. VMSs will be responsible for lower-level flight control. VMSs will use multi-source navigation solutions (e.g., the ability to continue flight in case of GPS loss) to navigate along MMS-defined flight paths.

Complete routes, from departure to arrival, will be planned by FOCs and filed with ATC for pre-negotiation for flow management and provision of applicable separation services. These routes will be passed to MMSs for execution. However, MMSs will also command speed and path changes to VMSs to execute interval management, DAA maneuvers, and LHA[13] maneuvers with MVS over-the-loop. MMSs will also be able to execute path changes associated with predefined contingency and emergency management plans as necessary.

3.1.3 Detect and Avoid

UAM aircraft must remain well clear of and avoid collisions with other airborne traffic as required by Federal Aviation Regulations 14 CFR Part 91, §91.111(a), §91.113, and §91.181. Detect and avoid capabilities (e.g., as provided by the Airborne Collision Avoidance System Xr) will enable uncrewed UAM to comply with these requirements.

This ConOps accommodates onboard or ground-based DAA and combinations of the two.[14] Considerations that will guide DAA system designs will include the size, weight, and power of onboard components, the latency and reliability of networks and communication links in ground-based DAA, and the potential effects of frequency congestion from multiple UAM aircraft using onboard radar and interrogating transponders in close proximity to major Class B airports.

3.1.4 Command and Control Datalinks

C2 datalinks between UAM aircraft and MVSs will be provided by radios onboard the aircraft and a secure, distributed, and deterministic network of radios that may include both ground and satellite-based infrastructure.[15] These datalinks will provide a means for MVSs to supervise and, if necessary, command UAM aircraft. These radios will provide sufficient service volumes to cover UAM operations, including all contingency and emergency branches on flight plans.

See section 4.2.1 for information on command-and-control communication service providers.

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[13] Landing Hazard Avoidance implementations may include both air, ground, or a combination of both systems.

[14] RTCA DO-365B provides eight classes of DAA systems, not all of which are expected to be suitable for UAM aircraft.

[15] RTCA DO-377A specifies the requirements for C2 datalinks.

3.1.5 Hazard Avoidance

UAM aircraft will be equipped and operated to avoid operational hazards beyond airborne traffic (e.g., terrain, hazardous weather, ground obstacles, etc.). Where available, UAM aircraft will leverage existing avionics (e.g., Helicopter Terrain Awareness and Warning System). Alternatively, UAM aircraft will leverage third-party services to provide real-time data on potential hazards (e.g., micro-scale weather for urban environments).

3.1.6 Contingency and Emergency Management

Because UAM aircraft will operate without an onboard pilot, they will require significant automation to address contingency and emergency situations. Initiation of contingency and emergency procedures will be primarily allocated to onboard automation, with notification of and supervision by an MVS.

Contingencies and emergencies may include the following:

- Loss of C2 link.
- Loss of DAA.
- Loss of GPS.
- Failures associated with the propulsion system.
- Failures associated with the energy storage system.
- Onboard medical emergencies.

This ConOps assumes that UAM aircraft will have sufficient onboard automation to respond to contingency and emergency events like those listed above and safely complete flights even in the absence of a C2 datalink. During such events, the onboard avionics suite will automatically execute pre-programmed contingency and emergency procedures (e.g., diversion); however, if the C2 datalink is still available, the MVS supervising the aircraft will be able to override these procedures if necessary.

For example, if a UAM aircraft enters a lost-link state, the aircraft will initiate specific procedures and protocols in an attempt to regain the C2 link with MVS on the loop. Fixed PBN procedures will allow the aircraft to continue the execution of the mission as planned, according to the last clearance received from ATC. The aircraft will automatically squawk 7400 if it cannot regain the link. The MVS will notify ATC via a secondary means and verify that the aircraft is squawking 7400. It will indicate that onboard procedures for a lost-link state are being executed. ATC will activate their lost link procedures. To ensure safe operations, the availability of landing sites along any point of the route in the event of a precautionary or emergency landing will be coordinated with the appropriate VMs.

In addition, procedures will be in place for offloading tasks from the responsible MVS when an aircraft is experiencing a contingency or emergency event that requires their focused attention.

3.1.7 Cybersecurity

Uncrewed, highly automated UAM aircraft will encounter ever-increasing cyber threats. To meet these threats, UAM aircraft will require robust and traceable compliance with airworthiness security regulations. These aircraft will follow RTCA DO-326A, Airworthiness Security Process Specification and DO-356A, Airworthiness Security Methods and Considerations, to show compliance with related regulations. Onboard security monitoring for electronic disruption should be standardized and available for implementation.

FOCs will monitor for disruptions in the security or digital trust within the operational fleet and use master caution warning indicators as inputs to flight operations. Security-relevant artifacts will be captured throughout the operational environment when there is impact to safe operations.

3.2 Fleet Operations Center

FOCs will be physical facilities that will host UAM aircraft operator personnel. These personnel will be responsible for planning and monitoring UAM aircraft operations. The key personnel located at FOCs will be fleet managers (FM), MVSs, and remote passenger hospitality personnel.

- **FMs will:**
    - Be responsible for fleet and resource scheduling.
    - Oversee pre-departure planning, resource scheduling, and dispatch.
    - Perform dynamic re-planning of fleet operations in the presence of weather or other operational disruptions.
    - Create mission intent for each UAM aircraft flight.
- **MVSs will:**
    - Be responsible for supervising multiple UAM aircraft.
    - Fulfill pre-departure and in-flight coordination with ATC.
    - Have the ability and command authority to override vehicle actions of aircraft under their control throughout flight.
- **Remote passenger hospitality personnel:** Remote passenger hospitality will be responsible for passenger health and provide safety communications to passengers before, during, and after flights.

FOCs will be designed to enable multi-vehicle supervision with an MVS-to-aircraft ratio of up to 1:3 in today’s NAS, using effective human-machine teaming applications. These same designs, as airspace services adopt higher levels of automation, are expected to operate at ratios of more than 1:3 as operations scale. As shown in Figure 3, each FOC will have multiple MVSs and workstations and one or more FMs.

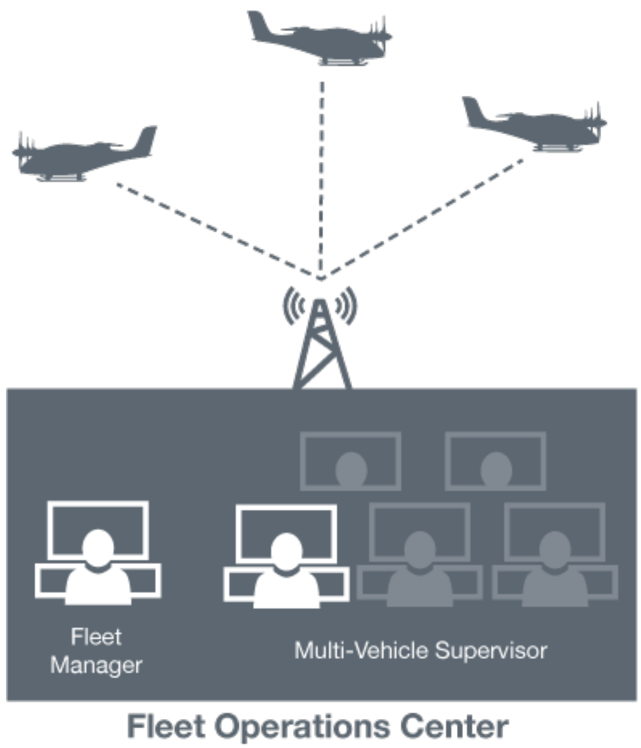

Figure 3. Fleet Operations Center

3.2.1 Integrated Operating Picture

The Integrated Operating Picture(s) (IOP)[16] will include a set of real-time operational information that will be accessible to UAM operators and VMs. This information will include:

- Vertiport reservation information (ledgers of slots and gate reservations, including secure ELZ allocations).
- C2 datalink spectrum reservations.
- Aircraft flow information.
- Real-time position and velocity (as with current Automatic Dependent Surveillance-Broadcast (ADS-B) messages).
- Weather information.
- Cyber master caution warning lights.

There will be two types of IOPs in the UAM ecosystem.

- **Centralized IOPs:** Centralized IOPs will be managed by a centralized entity and share information with various participants. Current-day examples of centralized IOPs include airline operation centers that pull information from centralized

[16] Operating Pictures as outlined in this ConOps may predate the Cooperative Operating Practices as outlined by the FAA UAM ConOps v2.0. It is expected that as the UAM ecosystem matures and scales, Integrated Operating Pictures will evolve into robust, practicable solutions.

System Wide Information Management (SWIM) and surveillance broadcast service network servers.

- **Decentralized IOPs:** Decentralized IOPs will be managed by a set of entities instead of a single, centralized entity. Current-day examples of decentralized IOPs include aircraft operating pictures that are formed through in-air ADS-B exchanges.

FOCs will use different IOPs to ensure all relevant data are available for safely operating UAM aircraft.

3.2.2 Fleet Manager

At each FOC, a FM, assisted by the automation in the FOC, will plan and schedule UAM flights, serving the formal role of flight dispatcher. Like current flight planning, scheduling, and dispatch, the FM and the automation will both depend on detailed information about the forecasted passenger demand, the airspace and vertiport capacities, and the airspace congestion (including low-altitude operations like small unmanned aircraft), as well as on supplemental information such as NOTAMs and Airmen's Meteorological Information.

3.2.2.1 Preflight Planning: Mission Intent Definition

Based on available information, FMs will create mission intent for each flight. The mission intent will coordinate all resources (e.g., aircraft, ground management, MVS, passenger hospitality, routes, vertiports, applicable flow management or ATC constraints, etc.) required for the flight. A 4D flight path, executed by the MMS with spatial and temporal buffers, will be generated and captured for the flight. This flight path will also include predicted energy consumption, reserves, potential contingencies, and alternate landing sites (including ELZs).

As aircraft departure time approaches, FMs will update mission intents with current and forecasted information to ensure an accurate prediction of energy consumption and reserves. Traffic flow integration that takes into account flight paths with other known UAM operations will be a critical part of this phase of mission planning.

Monitoring and updating mission intent before the flight will be a key activity of fleet management automation. For example, mission intent will be automatically removed when the flight is completed or if the operation does not become active within a defined time frame.

3.2.2.2 After Departure: Conformance Monitoring and Dynamic Rerouting

After departure, FMs will have awareness of overall flight operations and aircraft conformance to the original mission intent.[17] During system-level events (e.g., weather or disruptions that may restrict parts of routes), FMs will ensure a fleet-wide response and coordinate the fleet operations accordingly.

These types of revisions will leverage the same real-time operational information used during the flight planning to provide a mission intent that optimizes fleet performance and minimizes any negative system-level impacts.

FMs will assist MVSs, as required, in updating mission intent in response to observed adverse conditions (e.g., hazardous weather) or during in-flight contingency or emergency events. FMs will monitor for these types of situations and, if necessary, orchestrate a network-level response. MVSs will be responsible for approving any changes to the mission intent prior to UAM flight departure.

3.2.3 Multi-Vehicle Supervisor

MVSs will be responsible for supervising multiple UAM aircraft. MVSs will be supported by automation onboard the aircraft as well as automation in their MVS station (as part of the human-machine teaming FOC concept) to retain supervisory responsibility over UAM aircraft throughout all phases of flight.

Multi-vehicle supervision will be enabled by high levels of operational predictability and low levels of required human workload and cognitive bandwidth. Flight plans received from FMs will provide this predictability. The fidelity of flight plans and potential contingency or emergency responses will enable automated flight execution with a low level of workload by MVSs. For example, a robust UAM RNP Route Network and pre-negotiated Letters of Agreement (LOAs) with ATC will preclude most routine ATC interventions in UAM flights, enabling ATC to manage UAM aircraft by exception rather than routine instruction.

3.2.3.1 Adjusting Mission Intent

Prior to the flight, FMs will provide MVSs with mission intent for the flight under their supervision. The mission intent will contain "… all available information concerning that flight." (§ 91.103). This will include weather, charge and/or fuel (for hybrid electric) requirements, NOTAMs, temporary flight restrictions, known ATC delays, aircraft takeoff and landing performance (e.g., maximum allowable payload per the flight conditions such as density altitude), etc.

MVSs will review the mission intent and either accept or reject it. If an MVS accepts the mission intent, they will be responsible for the operation and safety of the aircraft and become the final authority for making or, if the source of a modification is external, approving changes to the mission intent and its execution. If the MVS, FM, supporting automation, or ATC identifies the presence of a hazard or future inefficiency (e.g.,

[17] Monitoring aircraft adherence to plan is a standard feature of current dispatcher systems.

weather, traffic congestion, airborne traffic), an adjustment to mission intent may be necessary prior to departure or during the flight.

Time permitting, FMs may be able to automatically coordinate updated flight plans with ATC and other automation systems. Updated mission intent will then be provided to the MVS for approval and upload to the aircraft. MVSs may directly initiate ad-hoc path changes caused by time-sensitive events (e.g., ATC vectors). The aircraft will maintain closed loop trajectories in case there is a loss of C2 link or energy safety thresholds are reached. However, these types of events will be rare, and most uploads to the aircraft will complete mission intent changes. Once updated, the new mission intent will be distributed to the automation systems of the FOC for use by the larger UAM ecosystem.

MVS approval of mission intent adjustments will not be required in the following situations:

- **Lost-link states:** During lost-link states, onboard avionics will execute pre-programmed contingency and, if required by additional failures, execute emergency procedures.
- **DAA resolution advisories:** DAA resolution advisories will be automatically executed onboard the aircraft to avoid near-midair collisions. Return to course may be automatic or commanded by the MVS.

3.2.3.2 Multi-Vehicle Supervisor Workstations

MVS stations will be the primary interface for MVSs to supervise and manage aircraft under their authority. MVS stations will provide an aggregated set of multi-vehicle information that will enable MVSs to execute routine operations and respond to contingency or emergency events.

Current ground control stations for remotely piloted aircraft provide a point of departure for the design of MVS stations. MVS stations will incorporate additional automation capabilities alongside the careful consideration of human-factor design principles for human-machine interfaces.

The interaction between MVS stations and UAM aircraft will be optimized around the exchange of the mission intent files. However, to respond to ATC vectors and commands, MVS stations will enable MVSs to command aircraft heading and altitude (similar to an autopilot interface used in aircraft today). During these types of operations, it may be beneficial to reduce the number of aircraft under the authority of a given MVS to prevent MVS task saturation.

MVS stations will also support the following functions:

- **Preflight checks:** Automation and ground management, supervised by the MVS, will ensure that all required preflight tasks, including battery level checks, flight line maintenance by ground management crew, vehicle configuration, and system health checks have been completed. This will also include verification that passengers have received a safety briefing from passenger hospitality management.
- **Cybersecurity checks:** Cybersecurity checks will monitor for intentional unauthorized digital interference as it relates to safe operations.

- **Aircraft and airspace operational status:** MVS stations will continuously monitor flights and ensure UAM aircraft are operating within limits in conformance with the mission intent. In addition, MVS stations will monitor vehicle health status, actual winds aloft, and energy reserves.
- **ATC voice communication:** ATC communications infrastructure will provide MVSs with the means for voice communication with ATC and other airspace participants.

3.2.4 Remote Passenger Hospitality

Remote passenger hospitality personnel located in FOCs will be responsible for the health of passengers during and after emergency and contingency events. This will include communicating with passengers and providing assurance throughout emergency and contingency events.

3.2.5 Information Management and Distribution

Information management will be a key design consideration for fleet management and FOC automation systems. The operations described in this ConOps will rely on multiple up-to-date, low-latency, high-integrity databases. These databases will provide UAM vertiport schedules and status, landing site and gate availability, the aggregated mission intent from other planned operations, and SWIM data from ATC.

Fleet management automation systems will provide the means to update the databases used by booking platforms or multi-modal service providers. These databases will provide customer-facing applications with the information required to provide appropriate notifications, alerts, and instructions to passengers. For example, a FM may provide an update that an aircraft scheduled to conduct a mission has been delayed. This update will be automatically provided to the UAM operators and booking platform service providers via an established application programming interface.

4 Urban Air Mobility Operational Environment

UAM aircraft operations will leverage the existing air transportation system to the fullest extent possible. However, as outlined below, the existing system's infrastructure and supporting services will need to evolve to support this ConOps. This ConOps leverages concepts (e.g., FAA NextGen, TSPs, etc.) and technologies (e.g., ADS-B In applications) already being developed by UAM stakeholders. It builds on a foundation of today's NAS, leverages new operational capabilities being deployed by NextGen, and adds elements of new third-party services and vertiport management.

4.1 Airspace

UAM operations will introduce a few new components specific to uncrewed operations into the existing airspace structure, published procedures, and operating rules. The following sections explore the utility and need for changes in four key areas of the NAS.

4.1.1 Airspace Classes

UAM aircraft will depart from, operate in, and land in uncontrolled (Class G) and controlled airspaces (Class E, D, C and B), as shown in Figure 4.

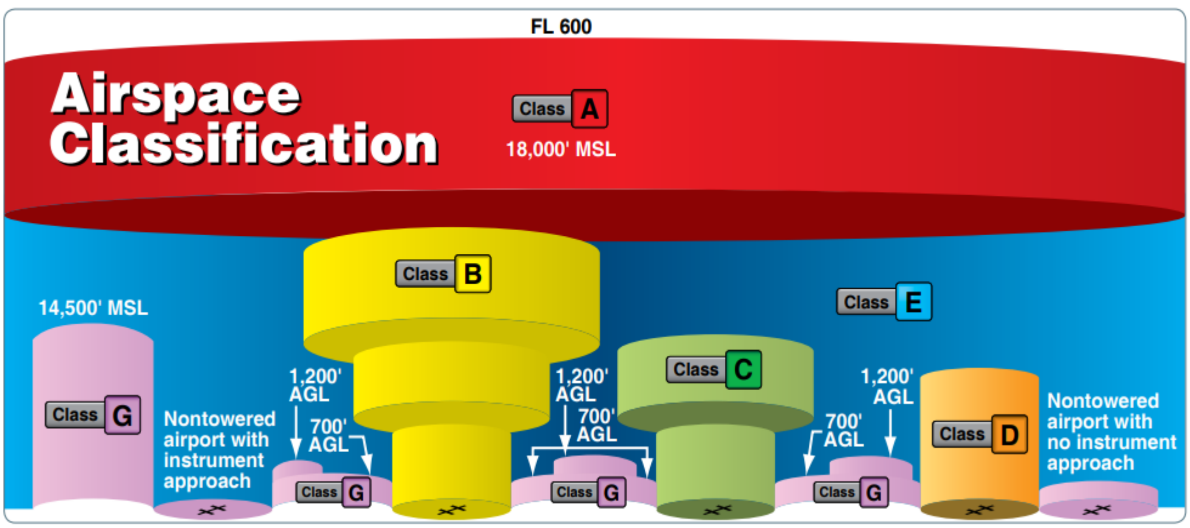

Figure 4. U.S. Airspace Classification[18]

Today, IFR operations, with associated ATC services, are operable in all airspace classes. Published procedures provide paths through busy airspace that help to minimize the potential of traffic conflicts. Traffic flow management balances demand with available capacity for forecasted conditions. Surveillance and voice communications are used for traffic control.

[18] Source: https://www.faasafety.gov/gslac/ALC/course_content.aspx?cID=42&sID=505&preview=true

4.1.2 Flight Rules

The ConOps in this document employs IFR constructs,[19] within the context of 14 CFR Part 91 Subpart B, while supplementing it with adjustments specific to uncrewed UAM aircraft operations. These adjustments lean on special flight procedures and letters of agreement (LOAs) reflective of waivers, exemptions, and special procedures for current operations of unmanned aerial systems in the NAS to extend the existing flight rule constructs. Modification of regulations made possible by the FAA's vision for an Infocentric NAS will enable operations with reduced interaction between air traffic controllers and the supervisors of uncrewed UAM aircraft.

The following attributes will form the basis for operational procedures that will allow MVSs to supervise up to three aircraft.

- Timely airspace information as reflected in the Integrated Operating Picture (i.e., vertiport, C2 datalink, traffic flow, real-time position and velocity, weather, etc.).
- Letters of Agreement between ATC and operators to achieve:
    - In-trail self-spacing along UAM RNP Routes.
    - Interval management for route merging points (incl. vertiports).
    - Reduced voice communications.
- Highly structured operations.
- Flight prediction accuracy.
- Operators' automatic flight tracking.
- Other digital information capabilities.

Previous human factors studies have informed some of the concepts outlined in this document. As this Midterm ConOps evolves, only the concepts proven safe by ongoing human factors assessments and validation efforts will be included as part of operations. Regardless, a necessary condition for the application of multi-vehicle supervision at any time is that it must be proven as safe as, or safer than, existing piloted operations.

In the midterm time frame of this ConOps, the initial operations of uncrewed UAM will engage ATC separation services as follows:

- ATC will provide traffic separation services in controlled airspace.
- UAM operators will submit flight plans to ATC for the short flights (30 minutes or less) to ensure effective demand and capacity balancing and flow management to increase predictability in the terminal areas of operation.
- UAM operators will consistently operate over fixed and predictable RNP routes and employ existing techniques (e.g., interval in-trail self-spacing and interval management) to keep ATC workload low.

This ConOps presents the use of system designs that enable M:N concepts (e.g., MVS stations and UAM aircraft). However, as previously stated, the ratio of supervisor-to-

[19] Aircraft equipped for IFR flight can use published routes and IFPs to prevent most conflicts with other traffic. This is enabled not only by the structure and organization of the routes and procedures, but also by the CNS infrastructure for the airspace in which the aircraft fly.

aircraft may vary based on the operator's operational specifications, capabilities, aircraft automation, standard practices, and agreements with ATC. All these requisites will enable each uncrewed UAM flight operation under this ConOps to be capable of meeting legacy IFR connotations (i.e., definition of a pilot, pilot responsibilities, and pilot requirements for ATC interactions), while being ultimately designed to support UAM scalability.

Key enhancements to flight operations will be as follows:

- **Takeoff and landing:** UAM aircraft will use procedures that enable fully automated takeoffs and landings with vertically guided initial and final segments.
- **Traffic spacing and sequencing:** Using in-trail self-spacing and interval management practices based on standardized agreements with ATC and between operators for applicable in-trail procedural separation (taking foundation from legacy traffic management initiatives for IFR traffic).
- **ATC communication:** Two-way voice communication between ATC and MVSs will be provided by either a VHF ground relay or airborne vehicle C2 link or, as available, by low-latency, party-line Voice over Internet Protocol (VoIP) network communications.
- **Energy reserve requirements:** Robust contingency and emergency management capabilities, including high-fidelity monitoring of the energy state and consumption during flight, will enable an equivalent level of safety to the legacy IFR reserve concept while reducing the amount of excess energy required for a given flight.

4.1.3 Instrument Flight Procedures

Where available, UAM aircraft will be able to use FAA-approved routes, SIDs, and IAPs, including missed approach segments (as well as arrival procedures if applicable).[20] These instrument flight procedures will provide 3D (lateral and vertical) guidance for landing and takeoff (e.g., lateral precision performance with vertical guidance, lateral navigation and vertical navigation, and Instrument Landing System). UAM aircraft will follow RNP along the IFPs, even in GPS-denied areas (this has been identified as an issue for a few of the current vertiport locations).

For uncrewed UAM operations in particular, additional instrument segments that provide guidance to the surface will supplement current procedures and replace a visual segment in current operations (e.g., from the decision altitude or decision height to the ground).

In order to deploy UAM operations more broadly, new vertiports (including vertiports on airports) will be developed with new approach and departure procedures that are unique to UAM aircraft operations. They will include guidance to and from the surface as these technologies and the commensurate approach design criteria matures.

UAM aircraft operators and relevant stakeholders will work together to establish new UAM RNP routes and IFPs. These will connect the system's vertiports and establish a

[20] The use of arrival procedures, in addition to approach procedures, may not be necessary for UAM operations, given the low cruising altitude.

complete UAM RNP route network that offers flight paths designed to be as direct as possible. These RNP route networks will enable efficient UAM operations while minimizing the need for tactical conflict management because, by design, they will not interfere with existing routes and each other.

4.1.4 Air Traffic Control Services

ATC will be responsible for separating traffic in most of the airspace where UAM aircraft will operate.[21] Air traffic controllers will be appropriately trained and qualified in the unique performance characteristics of UAM aircraft. They will be aware of UAM-specific RNP routes designed to maintain separation from other airspace users.

While not expected to be a common occurrence, MVSs will be enabled to respond to ATC radar vectors and direct UAM aircraft to follow the clearances and other IFR traffic management instructions.

4.1.4.1 Leveraging UAM RNP Routes

Due to onboard energy storage limitations, UAM aircraft will require high levels of operational efficiency and predictability. They will operate on RNP routes largely unique to their missions. To reduce mission variances, these routes will be planned to minimize encounters with other traffic. As a result, flight plans filed (or updated) just prior to departure should represent high-fidelity projections of the profile that will be flown.

By design, UAM traffic should demand little tactical intervention and be largely manageable by exception if the traffic remains on the filed UAM Route. In addition, operator-induced traffic-flow management and pre-coordination with ATC will further reduce potential traffic encounters by conditioning traffic flows to balance the demand with available capacity for the forecasted conditions.

Management by exception is used as the transition stage to the TSP-managed environment where legacy ATC is not expected to manage UAM traffic. Under this ConOps, UAM RNP Routes are assumed to be a transition stage between the regular IFR routes and TSP-managed environment, where ATC applies proper separation bounds to air traffic outside the UAM RNP routes but may intervene at any time and instruct all aircraft.

While UAM operations may significantly benefit from the application of 4D trajectories projections to their flight plans, this concept will likely be applied during the mature term, when TSPs take on increased levels of responsibility for airspace separation management. Autonomous UAM missions will use comprehensive 4D trajectories that augment the aircraft performance and the filed UAM Route and reflect associated flight intent. On the operator side, it will include projected time slots for passing the planned waypoints and appropriate time tolerances for proper sequencing of UAM aircraft on the UAM route. While the time dimension will not be used for traffic deconfliction, it will

[21] ATC is required to provide separation service between aircraft operating under IFR in controlled airspace (Class B, C, D, and E) as well as between aircraft operating under IFR and VFR in Class B and C airspace. ATC is not required to provide separation services for VFR in other airspace, though they may provide traffic advisories.

inform traffic-flow management and thereby ensure the viability of the arrival traffic sequence.[22]

A second important reason for establishing a robust UAM RNP Route network and associated procedures is the repeatability and predictability it provides, which, in turn, will significantly help in enabling practical automated conformance monitoring by FOCs and ATC. This will be essential for reducing workload and maintaining safety, as people are poor at simple monitoring functions. When automatic conformance monitoring detects a deviation from the planned waypoint crossing time that is large enough to affect traffic flow, it will be able to alert the MVS that a midflight re-plan may be needed. For example, this could happen should winds vary substantially from those forecasted for the route.

While not a prerequisite for any UAM operations, some terminal areas that have intricate traffic patterns and heavy VFR and IFR traffic flows may benefit from simple point-to-point UAM corridors established to smooth out NAS integration. These would be highly dependent on the environmental complexity and the operational benefits to the flight stakeholders in that area; hence, expected to emerge only after thorough airspace evaluations to ensure safety for all operations in the NAS.

4.1.4.2 Voice Communications

As air navigation service providers globally implement air traffic management systems that enable communications via VoIP, FOCs will be able to communicate with ATC over ground networks instead of analog VHF radio broadcasts. Where VoIP is not yet available, MVSs will be in two-way voice communications with ATC through the VHF radio on the aircraft via a relay over the C2 datalink.

Because UAM missions will largely occur in proximity to population centers, the airspace in which they operate will likely be terminal airspace associated with a nearby major airport (airspace class B or C, below a class B shelf, or within the Mode C veil[23]). Therefore, during UAM flights, MVSs will most commonly be in communication with terminal ATC (e.g., Terminal Radar Approach Control) rather than enroute ATC.

UAM operators will establish procedures and RNP routes that require minimal routine ATC voice communications for regular UAM operations in controlled airspace. Pre-coordinated LOAs and full flight clearances obtained prior to departure will support necessary ATC interactions and enable MVSs to serve in supervisory roles. ATC voice communications[24] under this ConOps will be infrequent and primarily tactical adjustments to the flight path for deconfliction with non-UAM traffic.

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[22] Overly strict timing for traffic deconfliction will either be limited due to inherent uncertainties or become a contract which must be met within a narrow margin and would, therefore, be prescriptive. The latter approach may introduce brittleness into the traffic flow or cause inefficient operations due to over-constraining the trajectory.

[23] Mode C veil refers to a type of airspace that currently surrounds all primary Class B airports within the United States.

[24] Certain necessary on-frequency callouts may be done using digital voice synthesis or pre-recorded announcements to support legacy IFR handling procedures.

4.2 Third-Party Service Providers

TSPs is a general term that includes different parties like Providers of Services for UAM (PSUs), Supplemental Data Service Providers (SDSPs), C2 Communication Service Provider (C2CSPs), etc. TSPs will enable UAM operations by providing the data and functions (e.g., weather information) required to enable safe aircraft operations as well as the services required to enable the UAM ecosystem at large (e.g., flight booking systems provided by multi-modal transportation services). The key services and associated service providers[25] are described in the following sections.

4.2.1 Command and Control Communication Service

MVSs will require a C2 datalink to command UAM aircraft. These datalinks will be required to maintain the operational tempo and efficiency in the UAM ecosystem. They will enable real-time communication and system-level optimization of UAM aircraft routing and operations.

C2 datalink equipment will consist of a Technical Standard Order (TSO)-approved radio that will be installed on the aircraft as well as a secure, deterministic, low-latency ground or satellite infrastructure that will provide connectivity with the FOCs.[26] Frequency and spectrum reservation may be required as part of flight planning to ensure that UAM operations will not be negatively affected by frequency congestion or lost-link states along routes.

As noted in Section 4.1.4.2, C2 datalinks may also be used as a relay for ATC voice communications over VHF radio. When this is the case, the latency associated with sending ATC voice via the C2 link through the VHF radio onboard must be limited to ensure that voice communications from aircraft are not negatively affected by onboard crew broadcasting on the same frequency.

In the event that an aircraft loses its C2 datalink connection, it will revert to a lost-link contingency mode of operation. Though this will reduce the efficiency of the larger UAM environment, it will not be an emergency contingency in which safety of life is threatened. As discussed in section 3, UAM aircraft will carry sufficient onboard automation to maintain the safety of the operation during a lost-link state; still, such events are expected to occur very rarely.

4.2.2 Detect and Avoid Service

RTCA DO-365B, Minimum Operational Performance Standards (MOPS) for Detect and Avoid (DAA) Systems, Minimum Performance Standards for Unmanned Aircraft System, defines DAA architectures that leverage detection of conflicting traffic entirely from the

[25] Some companies may subsume the role of multiple service providers.

[26] These systems are subject to RTCA DO-377A, as well as DO-362A (as modified by TSO-C213).

ground.[27] Traffic advisories will be provided directly to the MVS in the FOC, and, if necessary, directly to the aircraft for automatic execution.

DAA systems will need to provide sufficient coverage at the required performance specifications to allow UAM aircraft to leverage ground-based DAA systems. DO-365B defines different track performance requirements for terminal environments compared to enroute environments. TSPs of ground-based DAA will be required to demonstrate sufficient system and alerting performance for the entirety of UAM aircraft flight plans, including any branches associated with contingencies and emergencies.

4.2.3 Aeronautical Data Service

UAM aircraft operations will require a wide variety of validated high-integrity data to ensure safe operations. These data will include:

- Geospatial information.
- Terrain and obstacle information.
- Micro and macro weather information.
- Codified route and RNP NavSpec information.
- Aviation map information.
- NOTAM information.
- Temporary flight restriction information.

FOCs, as well as VMs, will consume the information as a key input to optimizing operations. While some of the datasets provided by supplemental data service providers will contain non-flight-critical data, this ConOps assumes that information sets containing flight-critical data will require FAA approval.

As a general assumption, supplemental aeronautical data used for UAM operations will leverage existing standards and formats.[28]

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[27] This ConOps considers both ground-based and airborne DAA.

[28] For example, RTCA DO-200A, Standard for Processing Aeronautical Databases, serves as a general standard for database processing, while individual databases meet specific standards such as DO-272C, User Requirements for Aerodrome Mapping Information, DO-276B, User Requirements for Terrain and Obstacle Data, or DO-291B, Interchange Standards for Terrain, Obstacle, and Aerodrome Mapping Data.

4.2.4 Booking Platform Service

Most UAM operators will integrate with third-party booking systems to generate a broad-based demand for their services. One example of this type of integration will be the combination of a UAM flight with ground transportation provided by a multi-modal service provider.[29]

4.3 Vertiports

Vertiports will be fixed locations where UAM aircraft will take off, land, load and unload passengers, and receive services (e.g., energy replenishment). Based on emerging market trends, vertiports may be operated by existing commercial FBOs. These FBOs will become VMs responsible for day-to-day vertiport operations and partner with UAM aircraft operators to ensure the efficient execution of UAM flights. Ground management personnel from UAM aircraft operators will be located at vertiports to ensure safe and efficient UAM aircraft operations.

Currently FBOs often manage every aspect of busy heliports; however, they are not official airspace control entities like air traffic control towers. The primary services provided by FBOs will include information provisioning and oversight during arrival procedures, gate marshaling, towing, and energy replenishment. FBO organizations can be trained and certified by third-party organizations and are not subject to FAA oversight. Without airspace control authority, it's likely that vertiport management entities will be trained and certified in a similar manner.

In some cases, LOAs with local ATC will establish operational constraints, clearance deliveries, and the roles and responsibilities for surface traffic management.

4.3.1 Vertiport Types

Vertiports will either leverage new facilities within the existing infrastructure or be completely new facilities. Existing infrastructure, including any ground systems required to enable the automatic and autonomic behaviors described in this document, will be further developed to meet the specific needs of UAM.

[29] Third-party platforms are subject to requirements defined in CFR Part 295 and Part 380 for public charter operations.

Table 2 defines three vertiports types and their key features.

Table 2. Vertiports Key Features

	Vertistop	Vertiport	Vertihub
Number of landing sites	1	2+	2+
Charging infrastructure	✓	✓	✓
VM support	✓	✓	✓
Gate infrastructure		✓	✓
Aircraft servicing	✓	✓	✓
Base maintenance			✓
Hangar space			✓

Vertistops, like helistops today, will often be located on top of skyscrapers and parking garages. To meet the demand in a city center, multiple vertistops in close proximity may be established in a coordinated fashion to ensure they can be used independently.

It is expected that vertihubs will be the base of operations for most UAM operators (like today's helihubs). Vertihubs will host vertiport managers, ground management personnel, and base maintenance staff capable of performing heavy maintenance, repair, and overhaul on UAM aircraft. Because of the large space requirements and urban real estate constraints, vertihubs will typically be located in industrial or suburban areas.

Vertistops, vertiports, and vertihubs may be co-located with airports (e.g., similar to general aviation terminals) or evolve from existing helistops or helipads (like those in Los Angeles and New York). Co-locating early vertiports will be advantageous due to the existing infrastructure, like terminals, with associated services for passengers and supporting CNS infrastructure.

If a vertiport is co-located with (or near) an airport, UAM operations will need to be integrated with other airport traffic in a manner similar to how helicopter traffic at airports is currently integrated. Keyholes (i.e., designed carve outs) in terminal airspace may be used to omit the airspace above vertiport locations from the tower controller authority and responsibility. This will allow a more efficient integration of UAM aircraft in the controlled airport environment and provide a degree of independence from the controlling airspace structure to aid in management of other airport traffic.

For example, as shown in Figure 5, it might be possible to have keyholes for the two vertiports closest to the airport, while the third vertiport would not need a keyhole because it is far enough away from the airport. These keyhole strategies are common in the NAS and are used to reduce the need to coordinate non-interfering traffic with air traffic flows at many major airports.

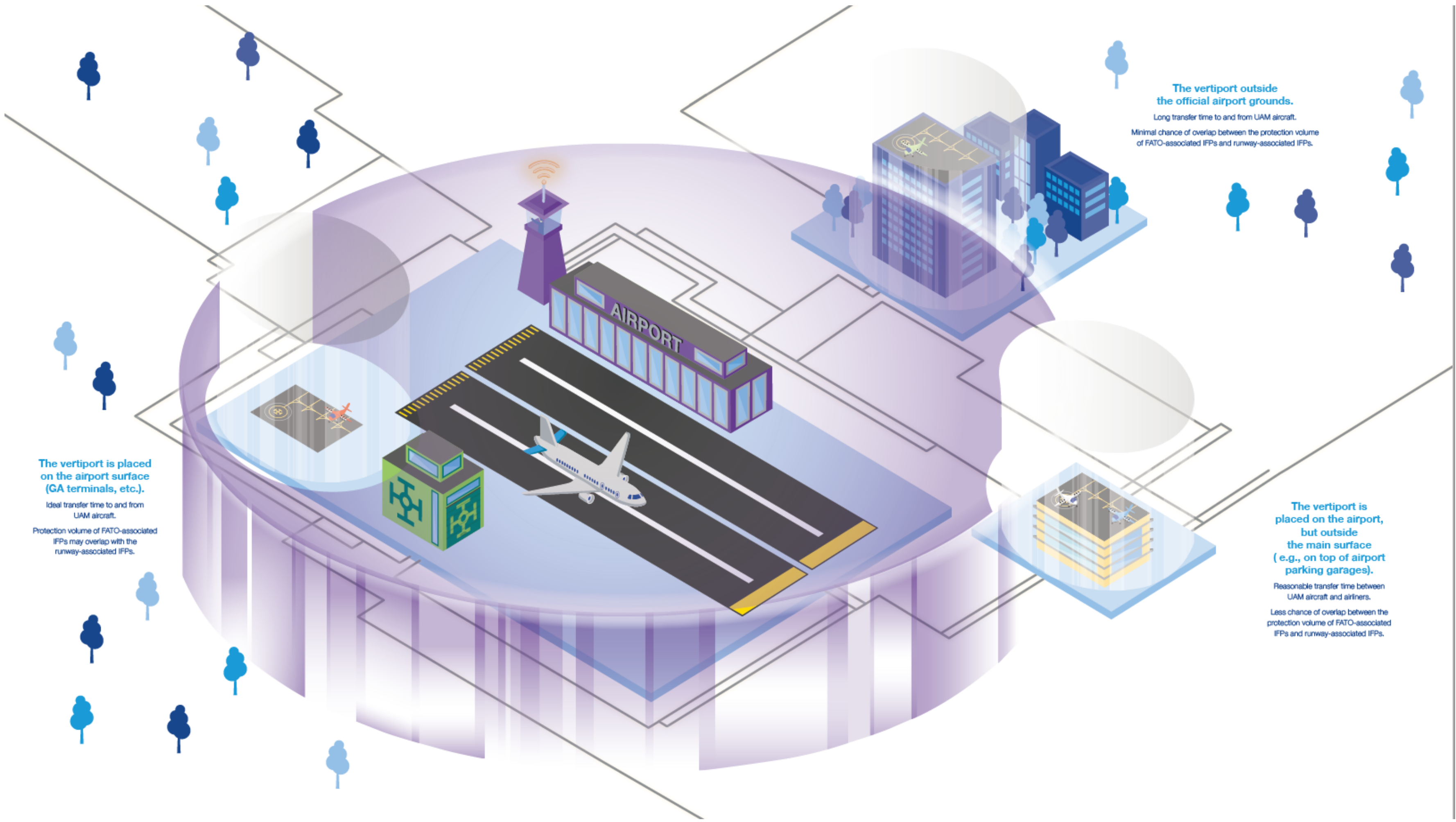

Figure 5. Keyhole Placement Strategy Example

4.3.2 Physical Design Attributes of Vertiports

Advisory Circular AC-150/5390/2C provides design guidelines for heliports in the United States; these guidelines can be used as a starting point for the design of UAM vertiports. This document specifies criteria for the size of touchdown and liftoff (TLOF) zones, FATO zones, and safety areas. It also specifies minimum separation requirements for simultaneous operations.

This AC will eventually be replaced by FAA engineering brief No.105. Figure 6, taken from this engineering brief,[30] shows an example of an elevated vertiport configuration.

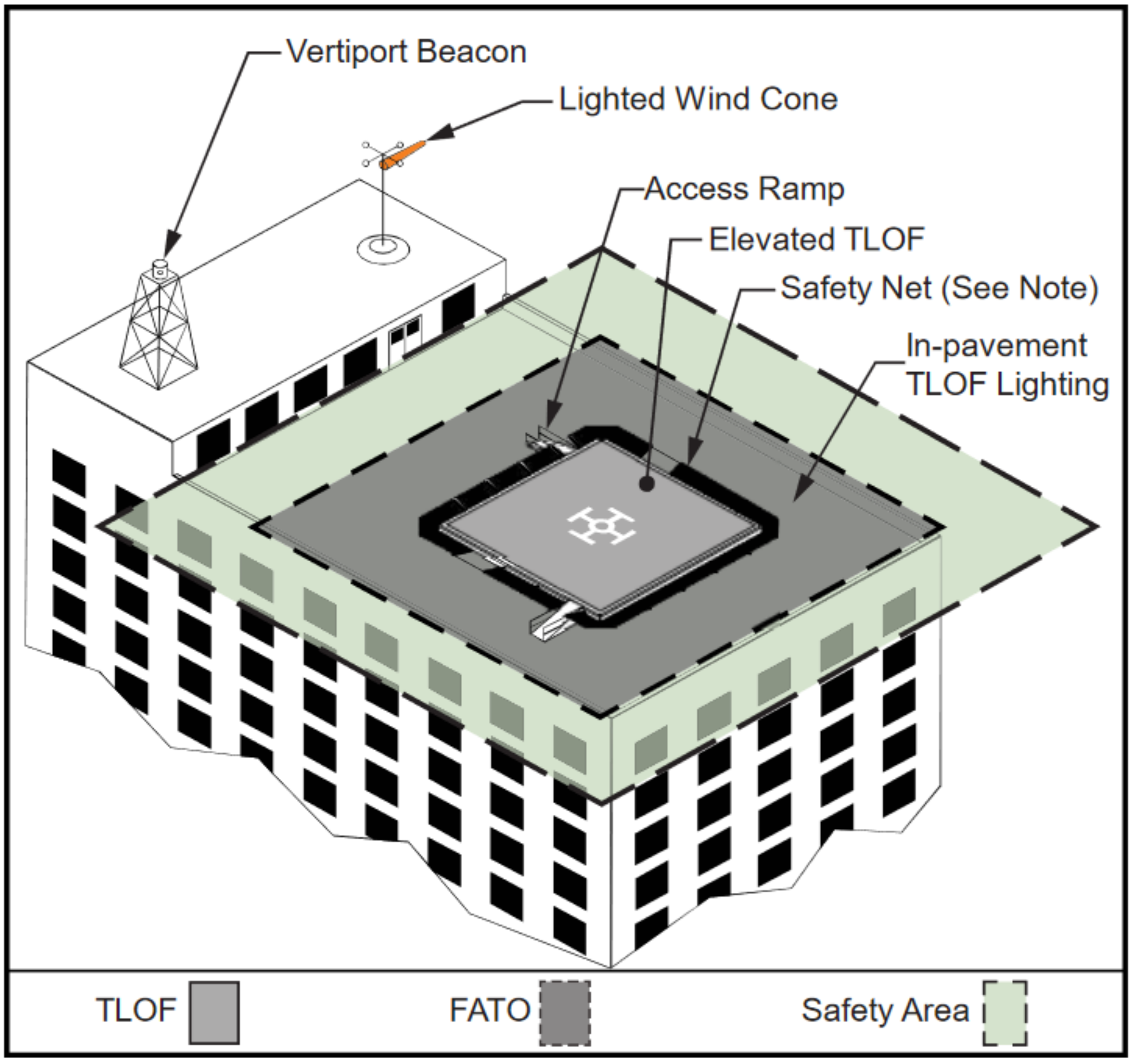

Figure 6. FAA Airports Engineering Brief No. 105, Vertiport Design

[30] Source: https://www.faa.gov/airports/engineering/engineering_briefs/drafts/media/eb-105-vertiport-design-industry-draft.pdf

In addition to the FATO and TLOF, vertiports will include passenger-facing terminal buildings and walkways, taxiways and gates, parking, and staging positions. These elements will be outside the movement area and will provide:

- Passenger access for embarking and disembarking aircraft.
- Power and cooling provisions for energy replenishment.
- Areas for flight line maintenance.
- Provisions for tying down UAM aircraft.

Each of these elements must be clearly marked, sized to fit UAM aircraft, and compatible with the intended operations. These elements must also align with existing or expected regulator or standards body[31] guidelines.

Vertiport capacity and flexibility will depend on the physical layout and footprint. Figure 7 shows three examples of possible vertiport topologies. Certain configurations and constraints may result in dependent aircraft operations, which, in turn, may reduce capacity and flexibility (e.g., vertiports placed on top of a building may be limited in physical size).

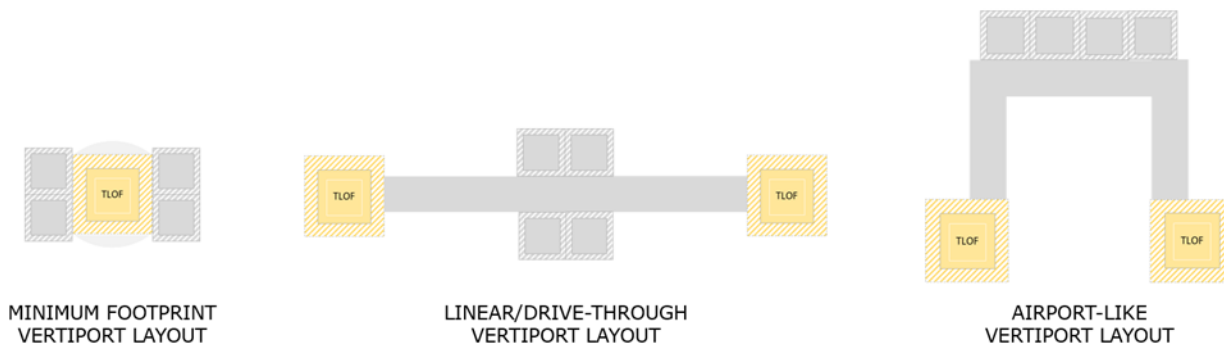

Figure 7. Vertiport Topology Examples

Legend: *Gray boxes are gates. Yellow boxes are FATOs with TLOFs. Gray rectangles are taxiways.*

The physical attributes of vertiports, including their height and location, the dimensions of their operational areas, penetrations of obstacle clearance surfaces, ground hazard information, etc., will be available to UAM aircraft operators. During the flight planning phase, this data will be considered to ensure hazard avoidance and maintain operational safety.

Vertiports will also require dedicated sensors for conformance monitoring and resource status evaluation. These sensors may include:

- Cameras and sensors on FATOs to detect aircraft touchdown and takeoff, FOD, and general occupancy.
- Close-range airborne object detection systems may be required in some cases to detect objects like birds, small unmanned aircraft, etc.

[31] For example, regulators include the FAA, ICAO, and European Union Aviation Safety Agency (EASA). See the FAA's draft EB-105 for additional vertiport design requirements.

4.3.3 Vertiport Alternatives

UAM aircraft will require alternative landing sites in case an event forces a precautionary or emergency landing before they reach their destination vertiport. This ConOps envisions three types of alternative landing sites:

Diversion vertiports: Diversion vertiports will be vertiports in the UAM route network with enough capacity to accommodate off-nominal landings. Diversion vertiports will be preferable to other types of vertiports due to the availability of passenger-related services.

Secure emergency landing zones: These will be sites along UAM RNP routes that will support efficient UAM flight planning where vertiports aren't available. They will provide the required services for approach and landing (e.g., position, navigation, and timing (PNT) and C2 coverage). VMs or UAM operators will establish ELZ automation systems that will provide surveillance status tracking of the ELZ.

Non-secure ELZs: Non-secure ELZs will be sites that have been surveyed and determined to be suitable for landing with minimal chances of encountering human activity on the ground (e.g., golf courses).

Figure 8 shows each alternative and an aircraft diverting to another vertiport due to an anomaly.

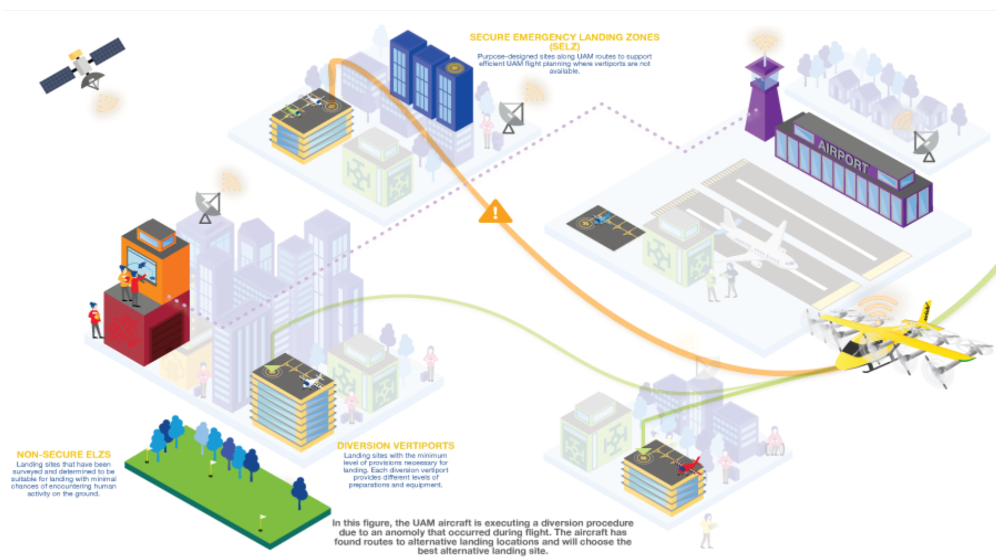

Figure 8. Off Nominal Diversion Flight Path

4.3.4 Communication, Navigation, and Surveillance Equipment

As discussed in section 4.2, TSPs will provide the C2 and DAA functions required to meet the performance requirements (including operations around a vertiport) along flight routes. Given the availability of the existing ground infrastructure, TSPs may choose to co-locate C2 and DAA equipment at vertiports. Regardless of the physical location of such equipment, the services provided by TSPs at vertiports will be required to ensure safe takeoff and landing operations.

Vertiports may also require additional communications to support operations on and around vertiports. This will include communications between VMs and FOCs, as well as communications between managers and support staff on the airport surface.

To meet PNT accuracy, integrity, and availability requirements for precision landing of UAM aircraft, GNSS PNT may be augmented with the Ground or Satellite-Based Augmentation System or an alternate PNT solution.

4.3.5 Meteorological Equipment

UAM vertiports will be provisioned with up-to-date weather information through onsite weather sensors.[32] These sensors will provide standard meteorological information, including temperature, pressure, density, precipitation, and 3D wind information. Ideally, the 3D wind information will be measured at various outer perimeter locations of the vertiport to avoid rotor wake interference.

4.3.6 Vertiport Management

A vertiport management entity (including a vertiport automation system) may be necessary to host UAM vertiport management and operational roles.[33] VMs will manage surface operations and provide the operational status of FATOs, ramps, taxiways, and gates to the larger UAM ecosystem. The primary services VMs will provide include:

- **Allocating resources:** VMs will oversee the allocation of landing sites, taxiways, gates, hangars, ramps, cargo and passenger processing, loading and unloading facilities, and equipment at UAM vertiports. Resource allocation may occur via automated resource negotiations with fleet management.
- **Controlling surface traffic:** VMs will determine taxiway, gate, or FATO availability, manage aircraft movement, and provide surface movement authorizations.
- **Airspace monitoring:** VMs will monitor the immediate vicinity of the vertiports and approach and departure IFPs to provide advisories on the airspace status and flight execution.

Some of these services will be highly automated.

[32] Data from automated weather or automated surface observing stations may be used in addition to vertiport-specific data.

[33] Similar to how airlines currently provide ramp control at busy commercial aviation hubs.

In some cases, LOAs with local ATC will establish operational constraints, clearance delivery, and roles and responsibilities for surface traffic management.

4.3.7 Ground Management

Ground management will include the personnel and systems that will perform the ground handling and flight line servicing of UAM aircraft at vertiports. Ground management personnel will be employed or contracted by UAM aircraft operators. These personnel will perform the flight line servicing required by UAM aircraft at the start and end of each day and between every flight. These operations will include:

- **Replenishing energy and cooling batteries:** Ground management will be responsible for charging aircraft batteries and performing associated cooling procedures.
- **Verifying aircraft are ready for flight:** Before aircraft are ready for departure, ground management will complete all relevant preflight checks. These checks will include verifying battery charge levels, ensuring automated system checks have been satisfactorily completed, verifying that the passengers and cargo have been appropriately secured, and confirming the aircraft system is secure and trusted, etc.
- **Assisting with passenger embarking and disembarking:** This role will involve handoffs between ground management and the passenger hospitality crew.
- **Towing aircraft:** This ConOps assumes that UAM aircraft will not be able to taxi under their own power. Therefore, ground management will be responsible for towing the aircraft between hangers, FATOs, and gates. Taxi procedures will not be required at vertiports without gates.
- **Turn-around procedures:** Ground management will perform UAM aircraft turn-around procedures. These operations (shown in Figure 9) will include:
    - o Initial checks on the FATO and attachment of the towing support system.
    - o Taxi-in operations.
    - o At-gate turn-around procedures, mostly driven by energy replenishment and passenger boarding operations.
    - o Taxi-out procedures.
    - o On-FATO taxi support system detachment and preflight checks.

Figure 9. Overall Turn-around Procedure Flow

Because MVSs will not be physically present at vertiports, ground personnel will be responsible for determining the airworthiness of UAM aircraft. Ground management personnel will be trained and certified to determine airworthiness. Ground management will also verify aircraft weight and balance after loading procedures are complete.

4.3.8 Onsite Passenger Hospitality Management

Onsite passenger hospitality management will include the systems and personnel located at each serviced UAM vertiport. These services may be provided by UAM aircraft operators or contracted from TSPs.

Passenger hospitality personnel will be trained in customer service and be deeply familiar with UAM operations and optimal passenger experience. The exact details of the qualifications and licenses these personnel will require will be determined by regulating authorities.

Their operational roles will include:

- **Safety briefings:** Passenger hospitality management will deliver safety briefings (typically through safety briefing videos) to passengers prior to aircraft departure. These safety briefings will inform passengers of the actions they should or should not take in the event of an emergency.
- **Interface with multi-modal transportation providers:** For scheduled passenger handoffs between UAM operators and other transportation service providers, passenger hospitality management personnel will welcome and direct passengers to the aircraft. Postflight, passenger hospitality management personnel will also ensure a safe handoff.
- **Assisting with passenger embarking and disembarking:** Passenger hospitality management will assist with passenger embarking and disembarking.
- **Emergency and contingency operations:** Passenger hospitality management will be responsible for the health of passengers during and after applicable emergency and contingency events.

4.3.9 Base Maintenance Management

The primary role of base maintenance management will be to maintain the continued airworthiness of UAM aircraft; the base maintenance personnel will be responsible for scheduled and unscheduled maintenance that is not part of flight line servicing. These functions will be in part achieved by using state-of-the-art aircraft health monitoring systems and following FAA-approved manuals and procedures that govern scheduled and unscheduled maintenance.

Base maintenance management will include advisory systems and personnel. Base maintenance personnel will be trained and certified per necessary regulations and have a deep understanding of aircraft inspection, maintenance procedures, troubleshooting and evaluation, and assembly and disassembly methods. In addition, base maintenance personnel will be capable of interacting with sophisticated and highly automated aircraft health monitoring systems and base maintenance management software.

The software will provide base maintenance management, ground management, and fleet management personnel with the tools they will need to:

- Ensure airworthiness.
- Schedule maintenance.
- Manage aircraft availability.
- Manage aircraft grounding for maintenance.
- Track training requirements.
- Capture aircraft health monitoring data for off-aircraft analysis.

Base maintenance management software will be used in conformance with the current manual maintenance instructions.

Through the aggregation of data for all UAM aircraft in operation, the base maintenance software platform will allow analysts to refine airborne health reporting algorithms and deploy postflight anomaly detection methods to flag potential emerging aircraft issues.

To ensure operator and customer data protections (e.g., anonymity), the software system will confirm that deployed analytics capture the operational data insights while always protecting operator or customer-identifying data.

It is important to note that original equipment manufacturers will be subject to certification requirements for creating and refreshing the maintenance and repair manuals that will be used by base maintenance personnel. These manuals will specify the time between overhauls and provide other important aircraft maintenance and repair information.

5 A Passenger's Journey

Commercial passengers will be the primary consumers of UAM aircraft operations. Figure 10 shows an autonomous UAM journey from a passenger's perspective.

Figure 10. Passenger-Centric Autonomous UAM Journey

5.1 Booking and Check In

Passengers will purchase seats on an existing flight or request a new flight through an online booking application. If a booking platform service provider also serves as a multi-modal service provider, passengers will have the option to book ground transportation through the same platform if needed.

Passengers may contact the booking platform service provider's customer assistance desk for help with the booking application and rescheduling or canceling flights.

When passengers arrive at a vertiport, onsite passenger hospitality will verify their booking and conduct security and weight checks.

5.2 Departure, Flight, and Arrival

Passengers will be able to enjoy food and drink and use the restroom if needed before boarding the flight. The VM will announce the flight-related information.

At boarding time, passengers will be escorted to the aircraft staging area, load their luggage, and take their seats. If required, boarding assistance will be available. Once in the aircraft, the passenger display will guide passengers through the onboarding sequence, and remote passenger hospitality will introduce themselves to the passengers.

Passengers will remain seated throughout the flight. They will have options for seat-to-seat communication, environmental controls, in-flight Wi-Fi, and charging.

A help button that will allow passengers to speak with remote passenger hospitality (if needed) will be available. Passengers will also be able to use the help button to trigger contingency or emergency scenarios if required during the flight.

After aircraft touchdown and tow-in to the gate, onsite passenger hospitality will open the doors, and the passengers will disembark and retrieve their luggage. Once they are clear of the staging area, the passengers will exit the service area and continue to their final destination.

6 Operational Vignette

This section summarizes key capabilities needed for uncrewed UAM operations and outlines the sequential flow of the procedures described in this ConOps.

6.1 Capabilities for Autonomous Urban Air Mobility Operations

The following is a summary of the capabilities that will be important for the introduction of autonomous UAM operations in the airspace:

- Real-time airspace awareness, vertiport status, and wind maps.
- High-integrity digital C2 communications.
- ATC voice communications via VHF radio relay over C2 datalink or VoIP ground network.
- ATC data communications (pre-departure at CPDLC-enabled airports).
- Precision navigation, including in GPS-denied conditions.
- Vertical autoland.
- Vertical auto-takeoff.
- Air- and ground-based DAA in both VMC and IMC.

Figure 11 shows how this ConOps embeds these important capabilities.

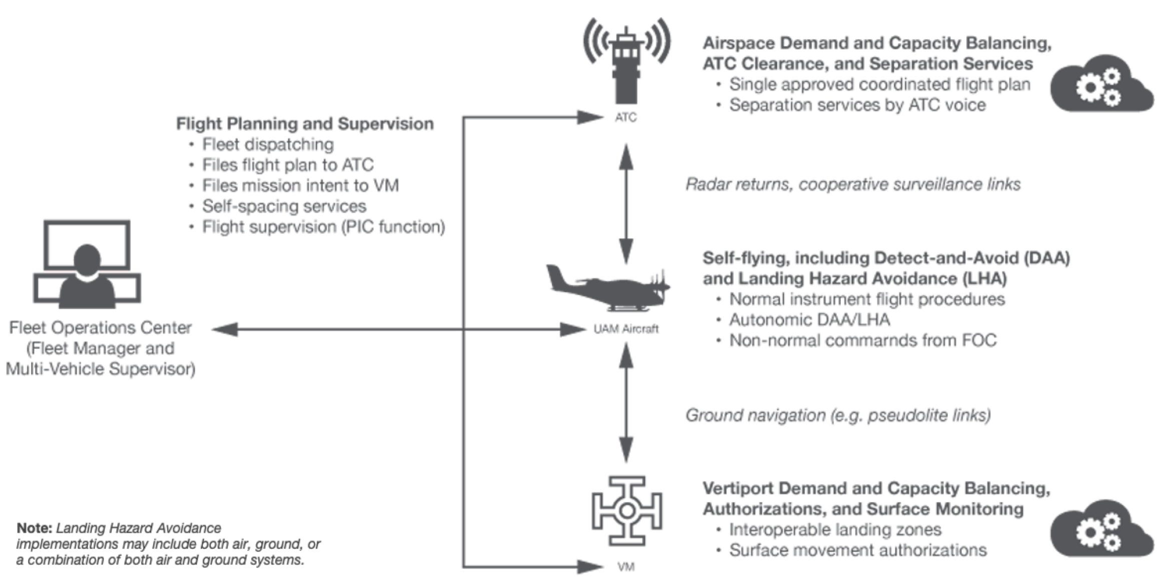

Figure 11. UAM System Functions with Embedded Enabling Capabilities

6.2 Operations

Nominal operational activity encompasses the standard operating procedures (SOPs) that will be required to provide UAM flight services. UAM operators will be expected to have regulator-approved SOPs that will specify these activities in detail and ensure safe operations.

There will be two major sets of SOPs. The first describes activities before the day of operations, wherein the FM will (a) build the fleet schedule, (b) define the initial flight plans, (c) allocate resources to meet slot reservations, and (d) submit the flight plans to ATC and the VM.

The second describes SOPs during the day of operations.

- **Preflight**: The MVS will review the flight plan, upload it to the UAM aircraft, and assume responsibility for the operation of the aircraft. Ground management will perform all required preflight checks.
- **In-flight**: This phase of operations will involve the departure, cruise, approach, and landing of the UAM aircraft. The MVS will receive authorization from the VM for surface movement at departure and arrival vertiports and clearances from ATC to depart and land.
- **Postflight**: Postflight, ground management will perform the required postflight checks and the MVS, UAM aircraft, and FM will file the required post-mission reports.

6.2.1 Flight Scheduling

Figure 12 shows the flight scheduling sequence and flow. Steps 1 through 3 provide additional details regarding flight scheduling activities.

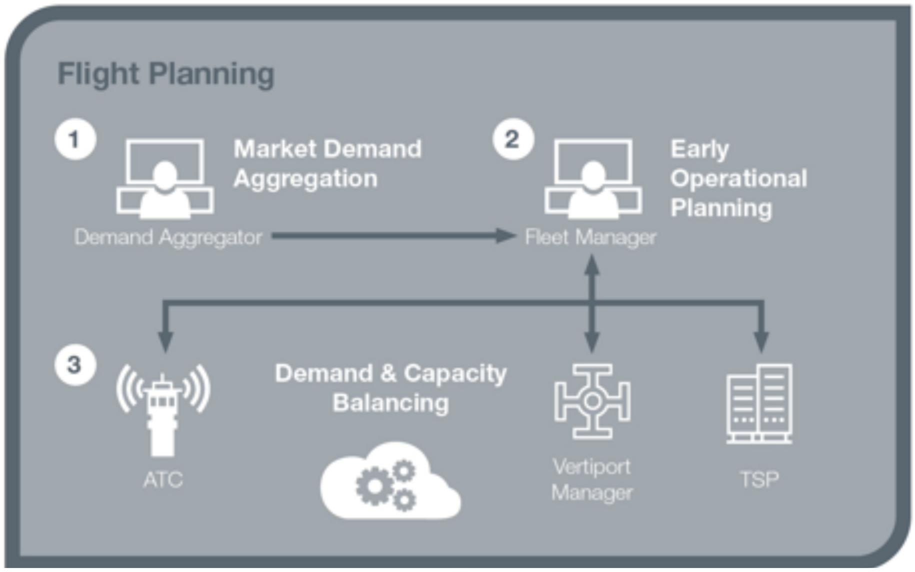

Figure 12. Flight Scheduling Sequence and Flow

1. **Market demand aggregation:** Flight scheduling for UAM aircraft will begin when the FM receives demand forecasts for flights between the UAM vertiports.

2. **Initial operational planning:** The FM will begin initial operational planning by turning demand forecasts into sets of viable mission intents. These mission intents will include ATC flight plans along with additional information unique to UAM operations (e.g., intended slot and gate occupancy at vertiports). As part of the activity, UAM operators will assess their internal fleet resource availability as well as their ability to access vertiports and airspace.

3. **Demand and capacity balancing:** The FM will submit the mission intent to the VM to initially reserve FATO and gate access during dedicated slot auction windows and ensure that support systems (e.g., suitable surface transport equipment) will be available. The FM will submit a flight plan to ATC for initial verification that there is enough capacity to support the proposed flight within the context of other submitted flight plans. In parallel, the TSP will reserve necessary spectrum for C2 datalinks to verify sufficient frequency capacity is available.

   The FM will continue to maintain the database of mission intents and adjust them if required by changing circumstances (e.g., vertiport closures).

6.2.2 Preflight

Figure 13 shows the preflight activity sequence and flow. Steps 4 through 7 provide additional details regarding the preflight activities.

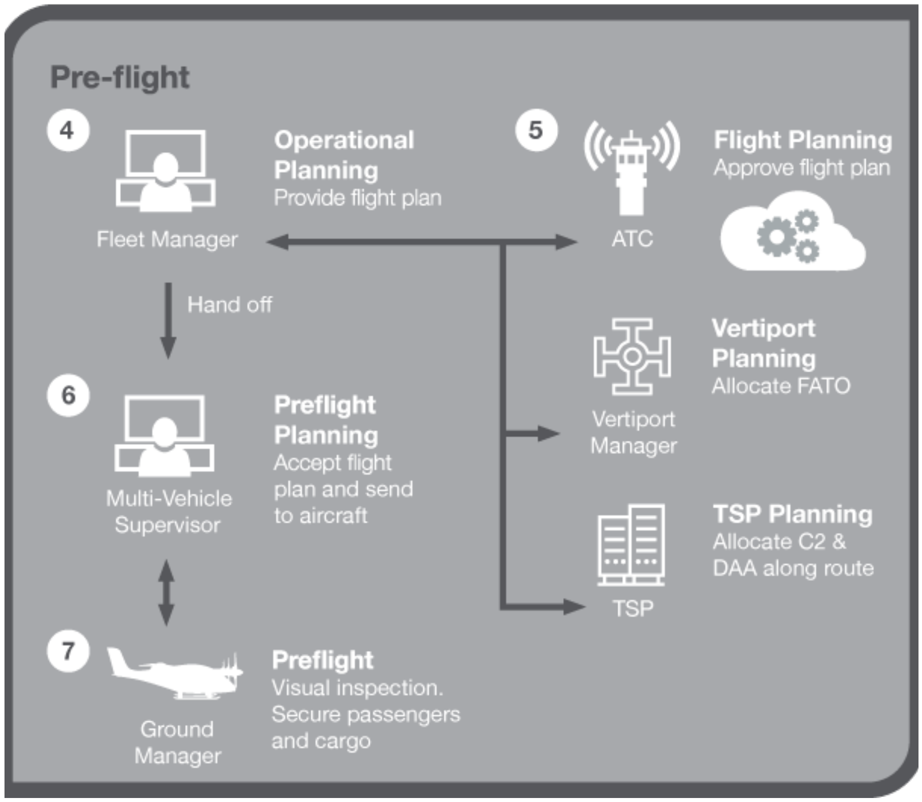

Figure 13. Preflight

4. **Continued operational planning:** Shortly before flight, the FM will update the initial mission intent with the latest weather forecast to create a high-fidelity mission intent. The FM will check the updated mission intent for any conflicts or new constraints.

5. **Air traffic, vertiport, and TSP planning**: Shortly before flight, ATC will officially approve the flight plan and, after ensuring demand and capacity constraints have been met, provide pre-departure clearance if applicable (nominally as filed). The VM will officially confirm that vertiport resources (e.g., FATOs and gates) have been reserved. In parallel, the TSP will confirm spectrum reservations for the C2 link and provide the validated databases and the real-time data products necessary for flight planning, IFP execution, and vertiport availability status. If conflicts are identified, the FM will initiate negotiations for a revised mission intent and flight plan.

6. **MVS acceptance**: When the high-fidelity mission intent is deemed free from conflict, the designated MVS will receive the mission intent, review the main details, and accept responsibility for the flight. After the MVS accepts legal responsibility for the mission, they will upload the mission intent to the UAM aircraft's avionics suite.

7. **Preflight checks and loading:** Ground management will perform the aircraft turnaround operations at the vertiport departure gate. These operations will include boarding passengers and loading baggage by the onsite passenger hospitality crew. Before the aircraft is ready to be towed for departure, ground management will ensure that all the relevant preflight checks have been completed. Once the preflight checks have been completed, ground management will inform the MVS that the aircraft is ready to be towed for departure.[34]

6.2.3 Departure

Figure 14 shows the departure activity sequence and flow. Steps 8 through 10 provide additional details regarding departure activities.

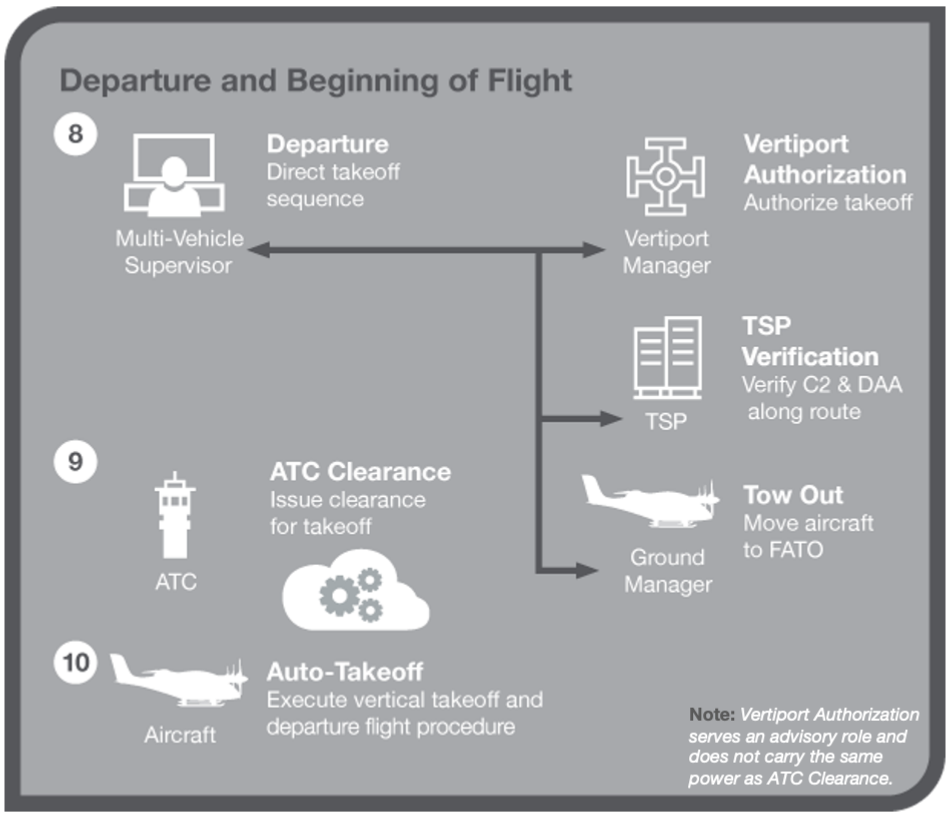

Figure 14. Departure and Beginning of Flight

8. **Tow-out coordination:** Prior to takeoff, the MVS will coordinate with the VM and ground management for towing operations to the FATO. The VM will provide vertiport surface movement authorization to tow the aircraft to the FATO.

   The UAM aircraft will depart from a vertiport FATO. If the aircraft is departing from a vertiport without gates (i.e., a FATO-only topology where the FATO is also used for ground servicing or boarding of passengers), the aircraft will not need to be moved.

[34] These checks will include verifying that the aircraft batteries have been appropriately charged and automated system checks have been satisfactorily completed.

9. **Takeoff clearance and authorization:** When the aircraft is ready for takeoff, the MVS will request a departure clearance for takeoff and execution of the entire flight plan. This will be subject to clearance confirmation at ATC boundary crossings along the route. The VM will also provide vertiport surface movement instructions for takeoff. The MVS will verify that the required TSPs along the route are available.

    a. If, for some reason, the UAM aircraft is not in position for takeoff during the takeoff window, the FM, the VM, and ATC will collaborate to determine a new departure time slot that maintains deconfliction requirements.

    b. Once a new time slot has been negotiated, the MVS will update the mission intent.

10. **Auto-takeoff:** After receiving the ATC clearance and VM instructions, the MVS will send an authorized for takeoff signal that will allow the aircraft to execute an auto-takeoff at some point in the takeoff time window. The MVS will retain control of the UAM aircraft and use the Integrated Operating Picture aggregated by the FOC to maintain awareness of the UAM aircraft's surroundings. The TSP will manage the C2 datalinks between the FOC and the UAM aircraft.

6.2.4 In-flight

UAM aircraft will use instrument navigation procedures and normally cruise between 1,200 to 4,000 feet AGL. During the in-flight segment, the MVS will follow ATC instructions to ensure appropriate aircraft separation. As a reminder, UAM aircraft operations will be designed with self-spacing and sequencing to ensure that in-flight instructions from ATC will rarely be required.

Figure 15 shows the in-flight sequence. Steps 11 through 13 provide additional details regarding in-flight activities.

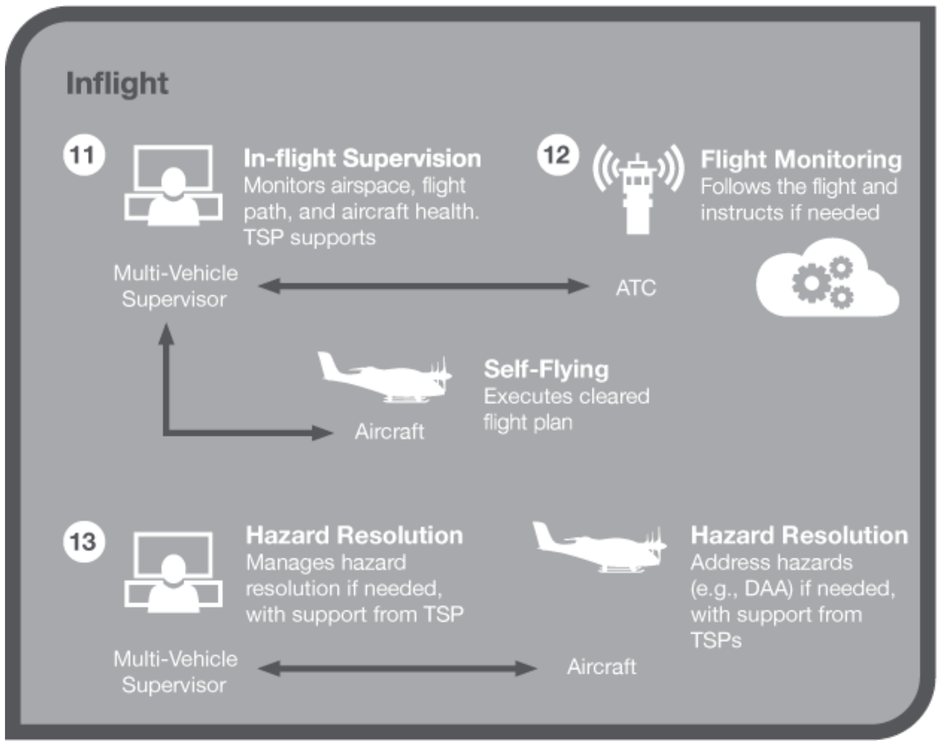

Figure 15. In-flight

11. **Operator supervision:** The MVS will monitor the Integrated Operating Picture and, should circumstances warrant, request approval from ATC to change the aircraft's speed, path, or both.

    Requesting changes will be operationally normal, though exceptional, due to the extensive real-time and historical stochastic information that will be used in flight planning.

12. **ATC monitoring:** ATC will be responsible for the flight as the designated separation authority. If needed, ATC will be able to direct the MVS to alter the flight path or speed of the UAM aircraft to maintain separation from other aircraft.

- While these types of directives are operationally normal, they will be rare due to the procedural separation provided by the design of the UAM route network.

- A typical flight will not normally require ATC separation interventions as the UAM aircraft will be able to autonomously fly on a specific UAM Route along its intended flight path to complete the flight plan as cleared at the beginning of the flight.

- When present on the route, handoffs and check-ins at ATC boundary crossings will be streamlined through voice communication automation and operational agreements. These handoffs and check-ins will serve as ATC communications integrity handshakes and, in the absence of any other ATC voice commands, provide consent to continue with the clearance provided at the beginning of the flight.

13. **In-flight hazard resolution:** The UAM aircraft or the MVS will resolve any hazards that occur during the flight. TSPs will also provide traffic and weather awareness information to the MVS and the aircraft to ensure the aircraft remains well clear of other aircraft in the area. Two examples of in-flight hazard resolution are provided below:

    - The UAM aircraft and the MVS station will have automated functions that continuously monitor the energy state of the aircraft. These features will help ensure that the aircraft always has sufficient energy to divert to a preplanned alternate landing site at any time during the flight. The aircraft will divert to an alternate landing site if the projected energy state becomes inadequate to continue the flight to the planned destination.

    - DAA capabilities, both on the ground and onboard the aircraft, will not be limited by meteorological conditions; therefore, the aircraft will always have DAA capabilities available. These capabilities will provide additional robustness to the UAM system operation if an unusual condition occurs. In addition, they will also provide a means of reducing controller workload.

    Because the MVS may be managing as many as three aircraft at a time, a conceivable scenario is that more than one ATC may be simultaneously issuing voice directives to the MVS. Though this is considered normal rather than a contingency, it will be exceptional since ATC will seldom need to issue directives. Even so, the MVS will always comply with ATC instructions in those instances. To ensure timely responses, MVSs will leverage operational capabilities and technical advances that draw on advanced human-machine teaming applications implemented in the FOC. Expanding on these implementations, potential examples include one-button automated acknowledgement and execution of instructions, MVS-to-ATC single-sector operations with MVS handoffs between sectors, multi-frequency monitoring for MVS supervising aircraft in multiple sectors, and others – all of which must be proven safe via human factors studies and operational testing.

6.2.5 Approach and Landing

Figure 16 shows the approach and landing sequence. Steps 14 through 17 provide additional details regarding approach and landing activities.

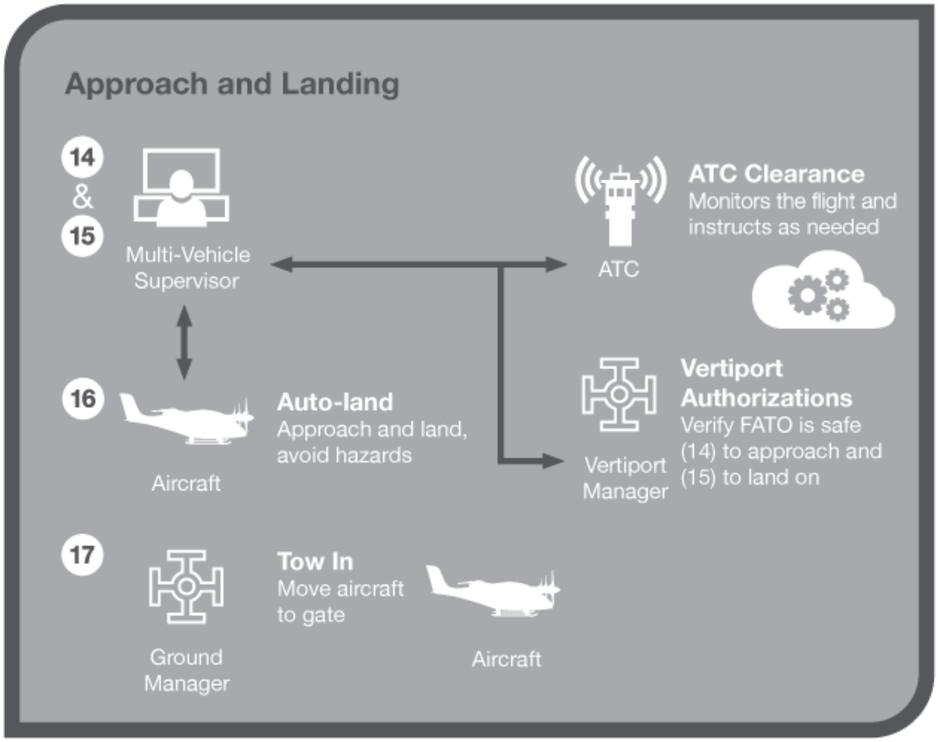

Figure 16. Approach and Landing

14. **Approach confirmation:** The MVS, VM, and ATC will (1) confirm that the previously established landing intent is still valid, (2) the landing slot is still available per the mission flight plan, and (3) ATC and TSP/vertiport surveillance show no unplanned approaching traffic. If required, ATC may issue off-nominal commands such as speed changes, holding patterns, path stretches, or diversions.

15. **Landing confirmation:** ATC will monitor the flight and inform the MVS if any clearance changes are required. In parallel, the VM will verify that the aircraft is safe to approach. If the required clearance and landing instructions have been received, the MVS will supervise the final landing segment.

    If the required clearance or landing instructions are not provided (i.e., an approach rejection), the MVS will decide if the aircraft should enter a holding pattern, adjust its arrival window and resume approach at a later time, or be diverted to an alternative vertiport.

    If the landing area is clear, the MVS will conduct a final system check and then execute the landing.

16. **Autoland**: The UAM aircraft will detect touchdown and automatically turn off its motors. The MVS will alert ground management that the aircraft has arrived at the

vertiport and notify the FM when the landing has been completed, and the aircraft has been disarmed. The MVS, in coordination with ground management, will independently verify that the vehicle has completed the disarming check procedure. ATC will be notified that the aircraft landed safely to close the active flight plan.

17. **Tow-in coordination:** If needed, ground management will tow the aircraft from the FATO to the gate once the VM provides the surface movement instructions.

6.2.6 Postflight

Figure 17 shows the post-flight sequence. Steps 18 through 20 provide additional details regarding post-flight activities.

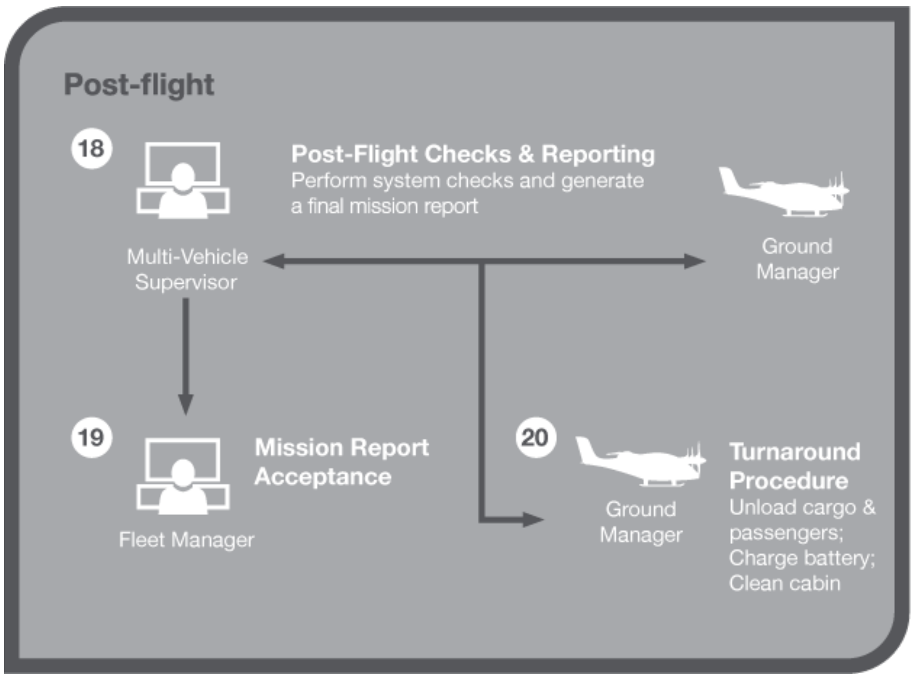

Figure 17. Postflight

18. **Postflight checks and reporting:** When the mission has been completed, the MVS, ground management, and UAM aircraft will perform various system checks and generate a final mission report that will be submitted to the FM. Once the mission report has been submitted, the MVS will drop the C2 link. Dropping the C2 link will release the MVS from responsibility for the aircraft.

19. **Mission report acceptance:** The FM will review and formally accept the final mission report and then store the information contained in the report for subsequent processing.

20. **Aircraft turnaround:** In parallel, ground management will execute the aircraft turnaround operations. These operations will include disembarking the passengers, unloading the baggage, and replenishing the aircraft's energy.

7 Working Together

This ConOps aims to facilitate stakeholder engagement and concept maturation and build industry consensus for how to enable UAM aircraft operations. Building this consensus will require engagement and collaboration between UAM industry stakeholders, regulatory agencies, and the workforce that will support UAM operations and communities that will be impacted by the integration of UAM in their airspace.

7.1 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 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, as described in this document, the introduction of supervised aircraft in the midterm 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 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.

7.2 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 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.

7.3 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.

8 Looking into the Future

A critical part of developing a UAM ecosystem is to not only realize the first introductory steps, but also upkeep the dynamic goals necessary to achieve a mature state. With high levels of automation being desirable for emerging flight operations, IFR and VFR, being extremely human-dependent, are unlikely to support the long-term expectations for scale and safety surrounding the UAM industry.

To overcome the limitations of legacy human-centric flight operations, looking at this evolution from a safety and scale perspective, an outline of certain expectations or milestones is required for the advancement of the UAM ecosystem across the Mid- and Mature states. Ultimately, these milestones lead to TSP/PSU enabled UAM Operations within a broader novel set of Automated Flight Operations or AFO.

It is important to acknowledge that the rulemaking effort, as outlined in Table 3, will span beyond UAM and involve the entire aviation industry. The new set of flight rules will make use of increased automation in the airspace, industry-wide technological advances, and aviation system maturation to improve operational scalability and achieve operational benefits of all flight operations worldwide.

While this document only reflects on the UAM use case of the AFO paradigm, the introduction of new flight rules will be all-encompassing to a variety of use cases (i.e., regional air mobility, large transport, etc.). More detail on the AFO paradigm will be introduced and expanded upon in a separate publication.

In the context of current FAA activities, AFO and the underlying infrastructure necessary to integrate with existing users and support at-scale UAM operations are reflected in the Agency's 2022 Info-Centric National Air System (ICN) initial Concept of Operations.

Within the ICN vision, the FAA has laid out a vision in which legacy Air Traffic Management Services co-exist alongside Extensible Traffic Management Services (xTM) supporting UAM. Table 3 provides an outlook for how stakeholders may evolve towards at-scale UAM AFO operations:

Table 3. UAM Roadmap to Operations at Scale

<table>
<tr><th rowspan="2"></th><th colspan="2">Initial UAM</th><th colspan="2">Midterm UAM</th><th>Mature UAM</th></tr>
<tr><th>Now</th><th>VFR Ops</th><th>IFR-expanded Ops
(this ConOps)</th><th>Initial AFO</th><th>AFO</th></tr>
<tr><td rowspan="2">ATS Routes</td><td>Regular T-Routes (incl. TK-ZK Routes)</td><td>Regular T-Routes catered to eVTOL aircraft</td><td colspan="2">UAM RNP Routes with between operator coordination for spacing and sequencing</td><td rowspan="2"></td></tr>
<tr><td colspan="4">RNP 0.3</td></tr>
<tr><td rowspan="2">Corridors</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td>Initial Point-to-Point AFO Corridors</td><td>Dynamic AFO Corridors</td></tr>
<tr><td>RNP 0.3</td><td>RNP 0.1</td></tr>
<tr><td rowspan="2">Terminal IFPs</td><td rowspan="2">Non-Precision Point in Space (PinS) Approaches</td><td colspan="2">Precision Approach and Departure Procedures
(akin RNP AR APCH/DEP)</td><td rowspan="2">Integration with Initial Point-to-Point AFO Corridors</td><td rowspan="2">Integration with Dynamic AFO Corridors</td></tr>
<tr><td colspan="2">Modifications to TERPS</td></tr>
<tr><td>Pilot</td><td>Onboard</td><td>Onboard</td><td>MVS
(up to three aircraft)</td><td>MVS
(average of three aircraft)</td><td>MVS
(many aircraft)</td></tr>
<tr><td>C2 Links</td><td></td><td colspan="4">Establishment of reliable C2 Links for BVLOS operations (i.e., ground UHF/C-Band, Low-Earth Orbit (LEO) Satellite</td></tr>
<tr><td>TSP/PSU</td><td>Initial PSU Prototype Trials</td><td colspan="2">Initial Certified PSU functions deployed (i.e., flight planning, integrated operating picture, conformance monitoring, etc.) w/o separation services (e.g., ATC maintains separation resp.)</td><td>PSU Certified Separation Services operating within AFO Corridors</td><td>PSU Certified capabilities deployed at scale as part of Info Centric NAS</td></tr>
<tr><td>Vertiport Automation System</td><td>Initial VAS Trials</td><td>VAS Trials supported by initial PSU integration</td><td colspan="2">VAS Deployment with some PSU integration</td><td>At-scale Interoperable Vertiports</td></tr>
<tr><td>FIMS</td><td></td><td>Trials for ATM-xTM Info Centric NAS Architecture</td><td>Initial certification for data exchange and xTM</td><td colspan="2">Deployment for data exchange and xTM</td></tr>
<tr><td>AFO</td><td></td><td colspan="2">Concept Maturation</td><td>Initial Rulemaking</td><td>Federal Regulations for new Flight Rules</td></tr>
</table>

Glossary

Acronym or Term	Definition
AAM	Advanced Air Mobility
ADS-B	Automatic Dependent Surveillance-Broadcast
AFO	Automated Flight Operations
AGL	Above Ground Level
AIM	Aeronautical Information Manual
ATAR	Air-To-Air Radar
ATC	Air Traffic Control
ATM	Air Traffic Management
C2	Command and Control
CNS	Communications, Navigation, and Surveillance
DAA	Detect and Avoid
EASA	European Union Aviation Safety Agency
ELZ	Emergency Landing Zone
FAA	Federal Aviation Administration
FATO	Final Approach and Takeoff
FBO	Fixed-Base Operator
FM	Fleet Manager
FOC	Fleet Operations Center
FOD	Foreign Object Debris
GNSS	Global Navigation Satellite System

Acronym or Term	Definition
GPS	Global Positioning System
IAP	Instrument Approach Procedures
ICAO	International Civil Aviation Organization
IFP	Instrument Flight Procedures
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
IOP	Integrated Operating Picture
LHA	Landing Hazard Avoidance
LOA	Letters of Agreement
MMS	Mission Management System
MVS	Multi-Vehicle Supervisor
NAS	National Air Space
NASA	National Aeronautics and Space Administration
NOTAM	Notice to Airmen
PBN	Performance-Based Navigation
PinS	Point-In-Space Approach
PNT	Position, Navigation, and Timing
PSU	Provider of Services for UAM
RNP	Required Navigation Performance
SID	Standard Instrument Departure

Acronym or Term	Definition
SOP	Standard Operating Procedure
SWIM	System Wide Information Management
TERPS	United States Standard for Terminal Instrument Procedures
TLOF	Touchdown and Liftoff
TSP	Third-Party Service Provider
TSO	Technical Standard Order
UAM	Urban Air Mobility
VAS	Vertiport Automation System
VFR	Visual Flight Rules
VHF	Very High Frequency
VM	Vertiport Manager
VMC	Visual Meteorological Conditions
VMS	Vehicle Management System
VoIP	Voice Over Internet Protocol
xTM	Extensible Traffic Management

References

14 CFR Part 91 - GENERAL OPERATING AND FLIGHT RULES, Subpart B - Flight Rules

14 CFR § 91.103 - Preflight action

14 CFR § 91.111 - Operating near other aircraft

14 CFR § 91.113 - Right-of-way rules: Except water operations

14 CFR § 91.181 - Course to be flown

14 CFR Part 121 - OPERATING REQUIREMENTS: DOMESTIC, FLAG, AND SUPPLEMENTAL OPERATIONS

14 CFR Part 135 - OPERATING REQUIREMENTS: COMMUTER AND ON DEMAND OPERATIONS AND RULES GOVERNING PERSONS ON BOARD SUCH AIRCRAFT

14 CFR Part 295 - AIR CHARTER BROKERS

14 CFR Part 380 - PUBLIC CHARTERS

Advisory Circular AC-150/5390/2C, Heliport Design

RTCA DO-200A, Standards for Processing Aeronautical Data

RTCA DO-272C, User Requirements for Aerodrome Mapping Information

RTCA DO-276B, User Requirements for Terrain and Obstacle Data

RTCA DO-291B, Interchange Standards for Terrain, Obstacle, and Aerodrome Mapping Data

RTCA DO-326A, Airworthiness Security Process Specification

RTCA DO-356A, Airworthiness Security Methods and Considerations

RTCA DO-362A, Command and Control (C2) Data Link Minimum Operational Performance Standard (Terrestrial)

RTCA DO-365B, Minimum Operational Performance Standards (MOPS) for Detect and Avoid (DAA) Systems, Minimum Performance Standards for Unmanned Aircraft System

RTCA DO-377A, Minimum Aviation System Performance Standards for C2 Link Systems Supporting Operations of Unmanned Aircraft Systems in U.S. Airspace

TSO-C211, Detect and Avoid (DAA) Systems

TSO-C212, Air-to-Air Radar (ATAR) for Traffic Surveillance

TSO-C213, Unmanned Aircraft Systems Control and Non-Payload Communications Terrestrial Link System Radios

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FAA UTM Pilot Program Technical Report

Guide to the Preparation of Operation Concept Documents

NASA Advanced Air Mobility (AAM) Portal

NASA ATD-2 Phase 1 ConUse

NASA/Deloitte UML-4 ConOps v1.0

NASA/NUAIR Vertiport ConOps v1.0

NAS Storyboards

For more information

https://www.wisk.aero/conops

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