**FEEDBACK**

This document presents an initial Concept of Operations (CONOPS) for integrating Urban Air Mobility (UAM) operations into the low-level airspace. Future refinements to the CONOPS will need to consider the perspectives of stakeholders. As such, we strongly encourage industry, government and communities to provide feedback. Your views will provide insight into the feasibility and practicality of the proposed concept and inform future implementation and system design requirements.

You can provide feedback through the Engage section of the Airservices Australia website, https://engage.airservicesaustralia.com. All feedback will be published on this site, as well as answers to any questions.
EXECUTIVE SUMMARY

Innovations in the aviation industry will soon lead to the certification and operation of a new class of aircraft called Electric Vertical Take-Off and Landing Vehicles (eVTOLs), which will be powered by electric and hybrid technologies.

The introduction of these new aircraft will enable Urban Air Mobility (UAM) operations to grow to an unprecedented scale. As a result, UAM operations may unlock new mobility options and economic opportunities for urban and regional communities. Recent analysis suggests that UAM is expected to result in 10.1 million annual trips by 2040 in a medium uptake scenario in Australia.1

The growth of the UAM industry will introduce new types of aircraft and supporting infrastructure. UAM aircraft will exhibit unique operational characteristics that are currently not catered for by the existing Air Traffic Management (ATM) system. UAM operations are expected to initially integrate with the current ATM environment. However, the expected increase in traffic density and frequency, when compared to existing traffic loads, and the need for UAM vehicles to operate in Instrument Meteorological Conditions (IMC), will present unique operational challenges. Furthermore, the proximity of operations to residential areas will increase the importance of community acceptance. EmbraerX and Airservices Australia have collaboratively developed a concept of operations (CONOPS) for the management of UAM vehicles—a concept called Urban Air Traffic Management (UATM). This CONOPS demonstrates how traffic management for initial UAM operations could be delivered safely today within existing ATM capabilities and scaled over time with the implementation of UATM Services.

UATM Services will integrate UAM operations into the low-level airspace. The Services will ensure that key performance attributes of the UAM environment including safety, flight efficiency, capacity, access and equity, flexibility and predictability are assured and maximised. Without an appropriate UAM traffic management system, the growth of the UAM industry will be capped, thereby limiting the benefits of UAM to both industry and society.

The collaboration has undertaken human-in-the-loop and fast-time simulations to begin validation of the concepts. Analysis of these simulations has identified that, in some locations, current ATM concepts will quickly become insufficient for managing new UAM operations. In addition, results indicate that UATM Services have safety, flight efficiency, capacity and predictability benefits.

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SECTION 1

INTRODUCTION

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1 INTRODUCTION

1.1 PURPOSE

This thought leadership document presents a model Concept of Operations (CONOPS) for the traffic management of Urban Air Mobility (UAM) vehicles—a concept called Urban Air Traffic Management (UATM). Many governments around the world are developing policy, as well as regulatory, technological and procedural frameworks to prepare for UAM operations. This document aims to inform future UAM development, both internationally and in Australia. In this document, you will find an operationally-sound concept for the introduction and growth of UAM operations. This CONOPS will evolve in response to feedback and we encourage you to share your views with both Airservices Australia and EmbraerX.

This document has been developed to inform local, national and international discussions regarding the design and specification of procedures and systems that could support UAM operations. The CONOPS is an example of how traffic management for initial UAM operations could be safely delivered today within existing Air Traffic Management (ATM) capabilities and scaled over time with the development of new traffic management services.

1.2 SCOPE

This CONOPS is focused on the traffic management systems (including procedural, technical and human elements) that will facilitate the initial operation and long-term development of the UAM industry.

It describes the likely phases of UAM operations from first introduction (with piloted, voice-based flights) to mature, high-density autonomous operations, albeit with different levels of detail for each phase. This holistic approach to integrating UAM operations is important as both short-term and long-term objectives must be considered to minimise the amount of rework and cost at a later stage due to initial design decisions. Where interaction with other airspace users is required (e.g. low-level helicopters or Unmanned Aircraft Systems [UAS]), this CONOPS describes how those interactions could be managed.

This CONOPS is a technical document and for any operations to be sustainable and successful, it is recognised that community engagement and consultation will be essential. This document does not yet focus on these issues or how they could be managed but acknowledges their importance in any UAM operation design and implementation process and may be addressed in subsequent versions.
1.3 CONTEXT

This CONOPS has been written to accommodate all types of vehicles, infrastructure and airspace classifications that will be part of the UAM ecosystem and environment. This ecosystem and environment include Electric Vertical Take-Off and Landing (eVTOL) vehicles, helicopters, General Aviation (GA) aircraft, UASs, airports and vertiports.

The concept has been designed to be globally applicable. UAM infrastructure, including traffic management systems, will need to be standardised so that products and services provided by government agencies and commercial organisations are consistent. Implementation of the concepts described in this document will be subject to policy decisions by individual countries.

The UAM industry will evolve. As such, this CONOPS is based on current knowledge and expectations of future UAM operations. Future versions of this CONOPS will be published as new information becomes available about the design and implementation of UAM, such as vehicle specifications and landing locations.

1.4 DOCUMENT STRUCTURE

This document is structured as follows:

- Section 2 introduces the key elements of UAM operations and low-level airspace.
- Section 3 describes the need for and purpose of UATM.
- Section 4 introduces the UATM operational concept. It provides an overview of the UATM Services that will support UAM operations and presents use cases that demonstrate the role of the services in a UAM flight.
- Section 5 provides a glossary of terms and acronyms used in the CONOPS.
- Annex A describes the relevant roles and responsibilities.
- Annex B provides a detailed description of the UATM Services.
- Annex C describes the results of simulation and analysis work that has been undertaken to support the development of this CONOPS.
- Annex D identifies the contributors to this CONOPS and the methodology followed during its production.
## SECTION 2

**UAM OPERATIONS AND LOW-LEVEL AIRSPACE**

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2 UAM OPERATIONS AND LOW-LEVEL AIRSPACE

This section describes the key elements of UAM vehicles, infrastructure, operations and low-level airspace that are important considerations in the UATM concept. Further details about roles and responsibilities are provided in Annex A.

2.1 UAM VEHICLES

UAM vehicles\textsuperscript{2} are expected to primarily be eVTOLs. In addition to electric designs, some Vertical Take-Off and Landing Vehicles (VTOLs) will be hybrids that use a combination of power sources. Helicopters will continue to be used as UAM vehicles. UAM vehicles will be used to carry passengers and/or cargo.

UAM vehicles will have a range of performance envelopes. Initially, new types of UAM operations will likely be limited to operating under Visual Flight Rules (VFR). However, it is expected that UAM vehicles will at some point need to operate in Instrument Meteorological Conditions (IMC).

Urban flights operate in proximity to buildings and highly populated areas for an extended proportion of flight time. When compared to UAM flights today that use helicopters, these flights will operate at a higher frequency and a greater density due to improved affordability.

UAM vehicles will have a pilot on board initially and will need to integrate with the existing ATM system and other airspace users (in particular outside controlled airspace) when operations commence. UAM operations are likely to be susceptible to the impact of weather (e.g. thunderstorms, reduced visibility and strong winds) as well as the effects of wind currents from tall buildings.

\textsuperscript{2} The term, \textit{air taxi}, is used by other organisations in some documents.
2.1.1 CAPABILITIES OF ELECTRIC VERTICAL TAKE-OFF AND LANDING AIRCRAFT

eVTOL operations will conduct detect-and-avoid through some combination of human (i.e. pilot-in-command) and technical systems, which may also incorporate off-board systems (e.g. ground-based detect-and-avoid). Initial eVTOL operations are expected to be piloted aircraft that will require voice communication capabilities, although some manufacturers are focusing development on remotely piloted and autonomous aircraft. eVTOL aircraft are expected to evolve towards autonomous operations with increasing levels of automation as technology and associated regulations mature.

Starting from initial operations, eVTOL aircraft are expected to carry the required equipment for day and night VFR operations. For initial operations, eVTOL aircraft will be equipped with Automatic Dependent Surveillance-Broadcast (ADS-B) to the same standard as required of other aircraft within the airspace category in which they operate. Beyond initial operations, to enable future detect-and-avoid responsibilities, eVTOLs are expected to be equipped with technology to support high-precision cooperative surveillance. This will be necessary because pilots’ ability to detect conflicts through see-and-avoid will become more difficult as operational density increases. eVTOL aircraft are also expected to be capable of high-precision navigation and self-conformance monitoring.

eVTOL aircraft will have limited battery power and, therefore, a limited range. They will have electric recharging capabilities and/or the ability to replace their batteries. These aircraft will need to have their batteries partially or fully recharged or replaced several times a day depending on the frequency, duration and length of each trip.

eVTOL aircraft will have some operational requirements in common with helicopters. eVTOL aircraft will need to take off and land in an appropriate wind direction.

---

3 This CONOPS distinguishes between the terms, automation and autonomy. When eVTOL operations rely on automation, a human remains within, or “on top of” the control loop. The human may be an on-board pilot and/or have an automation management, or supervisory, role. In contrast, during autonomous operations, there is no human involved for certain components of the eVTOL operation.
2.1.2 DIFFERENCES FROM HELICOPTER OPERATIONS

The key differences between eVTOL aircraft operations and helicopter operations are as follows:

- During the cruise phase of flight, some types of eVTOLs will use wing-based lift rather than rotor-based lift (as is the case with helicopters).
- eVTOL operations, varying by vehicle design, will often include a cruise period during flight, resulting in decreased manoeuvrability at this time.
- The noise profile of eVTOL aircraft will vary between designs but is generally expected to be quieter than a helicopter.
- As electric vehicles, and based on near/medium-term battery technology projections, eVTOL aircraft will not be able to hover for as long as helicopters.
- The reduced endurance of eVTOL aircraft will be a key characteristic that constrains how and where eVTOL operate, potentially requiring eVTOL-specific regulations and procedures that would differ from those used for helicopters.
- As electric vehicles, eVTOLs will need time and facilities to recharge their batteries between some, but not all, flights.
- As they are electric vehicles, UAM industry leaders are projecting that the cost savings from eVTOL operations will be passed to the consumer, thereby increasing accessibility to a previously price-prohibitive mode of transport.
- In some places, demand for high-density eVTOL operations is expected to be greater than the existing demand for helicopter operations due to improved affordability.

2.2 VERTIPORTS

A vertiport is an area of land, water, or structure used or intended to be used by VTOL aircraft to take off and land. A vertiport can have single or multiple UAM Final Approach and Take-Off Areas (FATOs). In the UAM operating environment, there will be a mix of vertiports with single or multiple FATOs.

A single vertiport may be established for a local area or there may be many vertiports within a local urban area operated by different organisations (similar to helipads in some cities). Existing helicopter landing sites could operate as vertiports provided they comply with relevant regulations. Vertiports may be dedicated solely to passenger transit, cargo loading, maintenance, or a mixture of these. Some vertiports will provide high-capacity, high-tempo facilities and integrate with other transport modes. Vertiports will be established more quickly than traditional airports.

Some vertiports will have facilities for UAM vehicles to move from the FATO to a stand so that the FATO is available for other vehicles (Figure 1). There will be a mix of vertiports with and without stands within the UAM environment. UAM vehicles will need places to park at a vertiport while not in operation. Transition between a FATO and a stand will occur while the vehicle is on the ground (either towed or self-propelled under its own power) or in a low hover.

Vertiports will be equipped with the necessary infrastructure to recharge/refuel UAM vehicles between operations. They will require navigation aids and/or visual cues with corresponding instrument flight procedures to enable safe operations during the night and periods of adverse meteorological conditions. Infrastructure and equipment requirements related to safety will need to be standardised at vertiports. Vertiports will need to be used by UAM or other vehicles at short notice in emergency situations. Subsequently, vertiports could be required to have a contingency FATO (or a secondary UAM vehicle landing site) to deal with emergencies or accidents that might occur at the vertiport or another nearby vertiport.

Vertiport capacity will significantly affect the capacity of the overall UATM system.

Image Page 14: Figure 1 - Example Vertiport
(Image provided by Skyports)

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4 The term, skyport, is used by other organisations in some documents. In this document, the term, vertiport, is considered to be interchangeable with skyport.

5 The area of land or water over which the final phase of the approach to a hover or landing is completed and from which the take-off manoeuvre is commenced.

6 FATO designation markings for vertiports are currently being determined by the industry’s standards bodies and regulators.
Vertiport capacity will significantly affect the capacity of the overall UATM system.
2.3 OVERVIEW OF UAM OPERATIONS

2.3.1 STANDARD (NOMINAL) FLIGHT
A UAM vehicle departs from a vertiport FATO toward another vertiport FATO. This flight may include a number of stops at intermediary vertiports. Intermediary stops could be required to position the vehicle for initial pick-up, or to pick up and drop off passengers and/or cargo. Trips can be planned in advance or on demand.

Pre-flight planning and flight management will include interaction with the UAM vehicle pilot and/or the fleet operator as well as vertiport operators. A fleet operator or pilot may want to make a trip in the urban environment along a specific track (horizontally and/or vertically) or hover for a period over certain locations for operations such as tourist flights.

2.3.2 NON-STANDARD (OFF-NOMINAL) FLIGHT
A UAM vehicle may need to change vertiport destination due to onboard reasons such as technical system failure, passenger/pilot issues, or changes in operational requirements. An off-nominal situation may also arise from external issues such as vertiport unavailability or weather. Vertiport availability issues will occur at short notice while the UAM vehicle is en route to its destination. A change in a UAM vehicle’s vertiport landing location will require a change in track.

Alternate vertiports or suitable forced landing locations will be required to be predefined prior to departure to ensure that external issues relating to the destination vertiport can be mitigated.

Changes to airspace access, such as Temporary Restricted Areas (TRAs) or Temporary Flight Restrictions (TFRs) can occur at short notice, while the UAM vehicle is en route. A UAM vehicle may need to change route to the intended destination when airspace access issues arise.

7 Roles and responsibilities are defined in Annex A.
2.3.3 **UAM FLIGHT PHASE DEFINITIONS**

The following phases of UAM flight are used in this CONOPS:

**PRE-FLIGHT**
Any activity related to preparation of the flight prior to departure, including vehicle pre-flight checks, vehicle charging, flight planning, boarding of passengers and/or cargo.

**DEPARTURE**
The period in which the UAM vehicle physically departs from the FATO or stand (if the vertiport has these) up to the point at which it reaches cruise altitude. Departure includes taxi, take-off and initial climb.

**EN ROUTE**
The point at which the vehicle reaches cruise altitude up to the point at which it begins the approach to the destination vertiport.

**APPROACH**
The period between the UAM vehicle aligning with the optimal track to the assigned destination vertiport FATO and reaching the decision point (or decision altitude/height). Descent is expected to occur within this phase. The UAM pilot will elect to either continue to land or climb to a safe manoeuvring altitude (executing a missed approach).

Should the decision be made to execute a missed approach, this will be considered an off-nominal component of the approach phase. Should a subsequent decision be made to reroute to an alternate destination vertiport, the approach phase terminates once reaching a safe manoeuvring altitude. Should the decision be made to continue to land, the approach phase terminates and the landing phase commences.

**LANDING**
The point at which the decision is made to continue to the destination vertiport from the decision point (or decision altitude/height) until the UAM vehicle lands on the vertiport FATO or taxis to a stand (if the vertiport has these).

**POST-FLIGHT**
The period after the UAM vehicle stops moving; the flight closes and securing the vehicle commences. Post-flight activities typically include de-boarding passengers and/or cargo and vehicle servicing activities (e.g. charging).

Turnaround is the time on the ground that incorporates post-flight and pre-flight phases.
2.4 LOW-LEVEL AIRSPACE

UAM vehicles will operate in low-level airspace\(^8\) (Figure 3). UAM operations are expected to operate primarily below 1,500 ft Above Ground Level (AGL) but will also operate above this level. Low-level airspace includes airspace outside of an urban environment. Other airspace users, including helicopters, hot-air balloons, UASs and fixed-wing aircraft will also use low-level airspace. In the future, there will be greater variety in the types of vehicles, operators and missions in the low-level airspace, including a mix of piloted and autonomous vehicles. No single category of operators will have exclusive use of airspace, and all operations will need to be integrated.

UAM vehicles will cruise above the majority of UAS operations which operate below 400 ft AGL. However, UAM vehicles will operate in the same airspace as UASs around vertiport locations, where flight paths need to exist at lower altitudes or where UASs will operate above 400 ft.

Depending on the flight path and destination, UAM vehicles will need to transit through what is currently categorised as controlled and uncontrolled airspace. Initially, UAM operations will take advantage of existing VFR corridors, transition routes, or existing helicopter procedures (for example, see Figure 4).

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\(^8\) When referring to UAM, some organisations use the term, advanced air mobility. Similarly, when referring to low-level airspace, some organisations use the term, urban airspace.
Operations at low altitudes in an urban environment will expose vehicles to mechanical turbulence from surrounding structures (e.g. eddies from tall buildings). In addition, operations at low level over built-up areas will have to consider the frequent erection of temporary obstructions (e.g. construction cranes) as the urban environment continues to develop.

Some airspace will be dedicated primarily to UAM vehicle operations. Conversely, there will be airspace from which UAM vehicle operations will be restricted. Some restrictions will be permanent (e.g. some military airspace) while some will be dynamic (e.g. emergency response or some forms of TRA/TFR). Traditional airspace users will periodically need to use airspace that is dedicated primarily to UAM vehicle operations. UAM vehicles will at times need to fly through controlled airspace to access airports or vertiports that are located close to airports.

UAM operations will need to be informed of non-cooperating UAS vehicles (i.e. those UASs that are not reporting their position to the UAS Traffic Management [UTM] or ATM). UAM operators will need to inform relevant airspace users about when and where UAM operations will be active. UAS operations will need to inform UAM vehicles of their operations around vertiports or when operating above a defined altitude.

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**Figure 4. Australian VFR Routes (Purple Dots) - Extract from Sydney Visual Terminal Chart**
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INTRODUCTION TO UATM

3.1 PROBLEM STATEMENT – THE NEED FOR UATM

The growth of the UAM industry will introduce new types of aircraft and infrastructure (vertiports) into the low-level airspace and urban environment. UAM aircraft will exhibit unique operational characteristics that are currently not catered for in the existing ATM environment.

Initially, UAM operations are expected to operate within the requirements of the current ATM operating environment in accordance with existing procedures and/or concessions that can easily be accommodated. However, the expected increase in traffic density when compared to existing air traffic and the need for UAM vehicles to operate in IMC in low-level airspace will present unique operational challenges. The proximity and frequency of operations to the urban community will also create important considerations. As the UAM industry matures, variations in the level of aircraft automation (including piloted, partially autonomous and fully autonomous operations) are expected to be in operation within the same airspace. Finally, the expected diversity in new technologies and aircraft types in the low-level airspace (e.g. UAS, UAM, low-altitude GA) presents traffic management challenges that cannot be solved by the current ATM system.

The existing ATM system has been constructed around the needs of existing airspace users. UAM operations necessitate different solutions to address issues, including

- urban canyoning,
- diversity in aircraft performance, automation and pilot capability;
- limitations of current Communication, Navigation and Surveillance (CNS) systems to accommodate a higher density of urban operations in VMC or IMC; and
- noise abatement.

In addition to the above, the existing human-centric approach to ATM will be very quickly overwhelmed, even by early UAM traffic growth.

In traditional aviation, a centralised system of traffic management is clearly defined. ATM services are provided by an Air Navigation Service Provider (ANSP), which enables safe and efficient aircraft operations. Building on many of the foundational principles of ATM, a new approach to traffic management is necessary to safely, efficiently, reliably, securely and equitably manage UAM traffic.

---

9 A concept wherein communications, navigation, and surveillance technologies currently in place can be severely degraded by urban interference such as terrain, buildings/obstacles, or terrestrial radio frequency interference.
3.2  THE PURPOSE OF UATM

UATM is the collection of systems and services (including organisations, airspace structures and procedures, environment and technologies) that support the integrated operation of UAM vehicles in low-level airspace. The objective of UATM is to support UAM operations and maximise the performance of UAM and low-level airspace.

UATM Services will integrate UAM operations into low-level airspace. These Services will ensure that key performance attributes of the UAM environment are assured and maximised as defined through Key Performance Areas (KPAs) applicable to ATM. This CONOPS adopts the KPAs of the International Civil Aviation Organisation (ICAO)\(^{10}\) as a way of categorising performance (Figure 5). ICAO promotes the use of a performance-based approach for

- "improving the effectiveness of the day-to-day economic management of their [organisations'] business,
- channelling efforts towards meeting stakeholder expectations and improving customer satisfaction, and
- managing change in a dynamic environment."\(^{11}\)

![Figure 5: ICAO Key Performance Areas](image)

All of ICAO's KPAs are relevant to the UATM CONOPS. Maximising performance requires the balancing of the outcomes of individual KPAs (e.g. ensuring flight efficiency as well as access and equity). Of all of the KPAs, safety must, without exception, meet acceptable levels as required under regulation.

---

3.3 RELATIONSHIPS WITH ATM AND UTM

Traffic management systems for UAM, UASs and traditional aircraft will need to interact with one another, or be integrated, to support deconfliction, shared situation awareness and collaborative decision making.

The UATM concept has been created to address the unique needs of UAM traffic management. For low traffic densities, initial UAM operations are expected to rely on current ATM services. However, as complexity increases, digitised and automated services will be necessary for some, if not all, elements of UATM Services. Provision of these digitised services will be achieved through UTM services, bespoke UATM Services, or a combination of both. As traffic density increases further and greater levels of aircraft autonomy are implemented, this is likely to bring about the need for highly integrated and unified airspace management across all traffic management systems.

3.4 UATM HORIZONS

This CONOPS uses three UATM horizons to describe the likely evolution of UAM operations (Figure 6). Each horizon will require different UATM capabilities to support operations.

Horizon 1 will see the introduction of eVTOLs for UAM operations. These UAM operations will be managed by procedures and technologies that are available within the current ATM paradigm (either locally or internationally).

Horizon 2 requires new ATM procedures and/or technologies that are not currently used by ATM and will introduce UATM Services to support UAM operations. These services will vary in service type and maturity, from initial procedures and services to full implementation. Horizon 2 will come quickly in some places due to the inability to reduce Air Traffic Control (ATC) workload using existing means. This has been demonstrated through a human-in-the-loop tower simulation described in Annex C. Trials of new procedures and technologies will be needed during Horizon 1 to support the case for Horizon 2 operations.

Horizon 3 is included within this CONOPS as it is important to develop implementation solutions that are strategically designed to be compatible with future autonomous operations. For example, introducing new voice-based procedures in Horizons 1 and 2 will not be appropriate for long-term industry growth considering that autonomous operations are anticipated. Operations are expected to increase in demand prior to autonomous UAM vehicle operations.
SECTION 4

UATM OPERATIONAL CONCEPT OVERVIEW

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4 UATM OPERATIONAL CONCEPT OVERVIEW

This section provides an overview of the UATM operational concept and includes subsections on each of the UATM Services that support UAM operations.

A set of UATM Services supports the achievement of the UATM objective. Two foundational UATM Services prepare the UATM environment for operation:

- Airspace and Procedure Design
- Information Exchange

In addition, four operational UATM Services provide capability for day-to-day UAM operations:

- Flight Planning and Authorisation
- Flow Management
- Dynamic Airspace Management
- Conformance Monitoring

Not all operational services (e.g., Dynamic Airspace Management) will be required to support initial UAM vehicle operations. The maturity of UATM Services will evolve as UAM traffic complexity or density increases. Each service will evolve in maturity at a pace commensurate with the growth of operations; i.e. some services will achieve higher levels of implementation maturity while others remain more basic. The necessary operational services and their level of implementation maturity at each UATM horizon will depend on the unique needs of each airspace environment.

An overview of the services is provided in this section, with a detailed description of each provided in Annex B.

4.1 AIRSPACE AND PROCEDURE DESIGN SERVICE

The objective of the Airspace and Procedure Design Service is to create airspace structures and supporting procedures that strategically maximise the performance of the available low-level airspace and minimise any additional impact on existing ATC and piloted operations.

The service will take into account the unique nature of UAM airspace needs and procedures to accommodate UAM within low-level airspace. Unique requirements or solutions will include the following:

- Vertiport transition zones; entry and exit points around the transition zones; arrival, departure and missed approach paths; consideration of various different obstacles in close proximity;
- Procedures for clearance into controlled airspace under VFR conditions;
- Design and implementation of dedicated UAM corridors within controlled airspace and the procedures that minimise ATC involvement/workload;
- Design and promulgation of UAM routes within uncontrolled airspace to reduce the likelihood of encounters with other VFR operators, terrain, and obstacles;
- Consideration of safety risk as part of the UAM corridor and route design through techniques such as quantitative Collision Risk Modelling (CRM);
- New classifications of airspace or reclassification of existing airspace to accommodate increased density of UAM operations;
- Deconfliction of UAM operations to the maximum extent practicable from existing airspace operations, including Instrument Flight Rules (IFR) flights;
- Community considerations with respect to noise abatement, ground risk, and visual pollution;
- CNS performance of existing aircraft in close proximity to UAM and the likely CNS performance of UAM over time; and
- Procedures for emergency and off-nominal operations.
4.2.1 PERFORMANCE EXPECTATIONS/BENEFITS (IN ICAO KPA TERMS)

An effective Airspace and Procedure Design Service enables UAM operations to achieve benefits in the following areas:

- **Safety** - Strategic segregation and/or separation\(^{12}\) of UAM aircraft from other types of aircraft, other eVTOLs and on-ground obstacles; reduced workload for ATC in managing UAM aircraft.
- **Environment** - The ability to position routes over less noise-sensitive areas (e.g. highways, train tracks, rivers).
- **Capacity** - Vertiport airspace design and procedures, which will maximise the capacity of the vertiport while maintaining appropriate levels of safety, noise, privacy and other risks or impacts.
- **Flexibility** - Increased efficiency due to the reduced likelihood of conflicting traffic.
- **Predictability** - Knowledge of where UAM vehicles can fly and increased likelihood of airspace access.
- **Access and equity** - Greater access to controlled airspace through the use of dedicated airspace structures and routes.
- **Participation and collaboration** - Provision of a structured means by which new vertiport infrastructure can be considered.
- **Global interoperability** - Standardised structures and procedures for the UAM industry used in different countries.

4.1.2 UATM SERVICE MATURITY PHASES

The following key points summarise the Service maturity phases (with further information in the detailed description of the Service later in the document):

- **During Horizon 1**, initial eVTOL operations will use either existing airspace structures and procedures or new structures and procedures that use existing ATM concepts.
- **Horizon 2** will necessitate the adoption of dedicated UAM corridors and routes and reserved airspace to allow segregation of UAM traffic from Regular Public Transport (RPT) aircraft and other airspace users.
- **In Horizon 3**, highly dynamic airspace structures, or fewer airspace structures, will be used where safety and other performance outcomes can be achieved through the application of more advanced technology and accompanying procedures.

\(^{12}\) Segregation ensures that two or more aircraft do not come into such close proximity that a threat to the safety of those aircraft exists. Separation is the concept of ensuring aircraft maintain a prescribed minimum distance from another aircraft or object, whilst meeting the associated condition(s), and requirements of the standard. (Airservices Australia & Department of Defence. (2020). *Manual of Air Traffic Services (MATS)*. Version 54. p. 54.)
4.2 INFORMATION EXCHANGE SERVICE

The objective of the Information Exchange Service is to ensure shared situation awareness for all stakeholders by exchanging timely and accurate data from the ANSP and industry systems. As a result, the Information Exchange Service will enable other UATM Services to support safe and efficient operations.

Information Exchange must be aligned with ATM information management principles as far as is practicable. Information Exchange will provide accredited, quality-assured and timely information that will be used to support UAM and related operations. It will also monitor and control the quality of the shared information and provide information-sharing mechanisms that support UAM stakeholders.

The best possible integrated picture of the historical, real-time and planned or foreseen future state of the UAM environment will need to be assembled. This integrated picture will provide the basis for improved decision making by all UAM stakeholders.

Information Exchange will enable the wide availability of high-quality, relevant and consistent digital aeronautical data. The data will be presented to all users in a usable format and will contribute to increased safety and UAM operational performance. UAM stakeholders will depend on information, shared on a system-wide basis, to make informed collaborative decisions for business and operational outcomes.

Within the UATM system, based on this operational concept, it will be the information that will be of significance rather than the technology that supports it. Pertinent information will be available when and where required. UATM data will have temporality, but to varying degrees in terms of frequency and/or magnitude, varying from almost static to highly dynamic. Information will need to be tailored, filtered, and accessed by users with different permissions and needs.

The initial quality of the information provided will be the responsibility of the originator; subsequent handling must not compromise its quality. The Information Exchange Service will allow all participants to adjust information-sharing to mitigate any proprietary concerns. Sensitivity with regard to some data will continue to be an issue and will be managed within the Information Exchange Service.

Information Exchange will achieve a seamless transfer of relevant information between parties in a flexible, adaptable and scalable information environment. The Information Exchange Service will use globally harmonised digital data standards.

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13 As defined in ICAO. (2005). Global air traffic management operational concept (Doc 9854).
4.2.1 PERFORMANCE EXPECTATIONS/BENEFITS (IN ICAO KPA TERMS)
An effective Information Exchange Service enables UAM operations to achieve benefits in the following areas:

- Timely and accurate information is the basis of all performance management. Effective Information Exchange enables UAM operations to achieve benefits across all performance areas.
- Importantly, information security assurance will be fundamentally based upon the approach used for Information Exchange.

4.2.2 UATM SERVICE MATURITY PHASES
The following key points summarise the Service maturity phases (with further information in the detailed description of the Service later in the document):

- During Horizon 1, some Information Exchange could be provided at a vertiport through services similar to an Aerodrome Flight Information Service (AFIS) along with other automated ATM services. Initial UAM vehicles will be piloted, incorporating voice communications as part of the Information Exchange. Provision of a vertiport FATO reservation method will be necessary for Horizon 1.
- During Horizon 2, the exchange of information with all key stakeholders, including vertiport operators, fleet operators, the booking platform, vehicle operators, the ANSP and USSs will commence. As a foundational service, a mature Information Exchange Service will be needed to support the density and frequency of operations expected in Horizon 2.
- By Horizon 3, reduced reliance on current ATM technologies, including voice-based communication, will enable the introduction of autonomous UAM vehicles.
4.3 FLIGHT PLANNING AND AUTHORISATION SERVICE

The objective of the Flight Planning and Authorisation Service is to develop and maintain a plan and issue an authorisation in response to a flight request for a UAM vehicle movement. The flight plan and authorisation must align with the strategic objectives of the overarching UATM system (e.g. flow management constraints).

A flight authorisation is the clearance for a UAM flight, the flight plan and a reservation for vertiport use. Where the provision of UATM Services is mandated, all UAM operations will require a flight authorisation. Flight planning requires a centralised element to ensure that all UAM operations take into consideration vertiport and airspace capacity and availability. A key component of flight planning is ensuring equitable access for all airspace users.

Strategic deconfliction is delivered through airspace structures and procedures, while pre-tactical deconfliction is delivered through trajectory management. Responsibility for tactical deconfliction remains with the UAM vehicle pilot through see- or detect-and-avoid capabilities. However, the Conformance Monitoring Service described later will contribute to tactical deconfliction.

A mature Flight Planning and Authorisation Service will include the use of 4D trajectories. 4D trajectories will provide a basis for pre-tactically deconflicting UAM vehicles across the whole flight and will take into account the UAM vehicle performance characteristics. Flight planning will need to consider energy usage and vehicle endurance as part of the plan. It will also need to consider weather conditions and their potential effect on energy usage and vehicle endurance.

4.3.1 PERFORMANCE EXPECTATIONS/BENEFITS (IN ICAO KPA TERMS)

An effective Flight Planning and Authorisation Service enables UAM operations to achieve benefits in the following areas:

- **Safety** - Pre-tactical deconfliction of UAM vehicle movements near vertiports and along routes/corridors.
- **Environment** - Adherence to environmental or noise obligations regarding vertiport and route/corridor usage.
- **Capacity** - Planned use of vertiport FATO resources ensuring the greatest use of the limited resources to maximise capacity.
- **Flight efficiency** - Timed use of vertiport FATO resources and use of routes/corridors minimising the airborne holding of UAM vehicles.
- **Flexibility** - The ability to plan in advance, request on demand and make changes to flight requirements.
- **Predictability** - Assurance of vertiport FATO accessibility for departure and arrival and route/corridor availability.
- **Access and equity** - Assurance that all airspace users can gain access to the low-level environment.

4.3.2 UATM SERVICE MATURITY PHASES

The following key points summarise the Service maturity phases (with further information in the detailed description of the Service provided in Annex B):

- Initial implementation of the Flight Planning and Authorisation Service will focus on vertiport FATO availability, as initial route/corridor structures will not yet be available and initial numbers of vehicles will be small.
- As dedicated UAM airspace structures are established, route/corridor planning will be included within the Service.
- To increase efficiency and capacity, 4D trajectories will be implemented. This Service is expected to reach full maturity during **Horizon 2**.
4.4 FLOW MANAGEMENT SERVICE

The objective of the Flow Management Service is to ensure that demand for UAM operations is met to the greatest extent practicable in the context of the limited resources in the airspace and vertiports. To maximise the capacity of vertiport FATOs, Flow Management will be required to manage arrival and departure times and slots. Flight planning will be informed by the capacity available at each vertiport. If capacity changes at a vertiport, previously planned flights must be reviewed to ensure that vertiport capacity is not exceeded.

Flow Management will be used to inform updates to flight plans based on changes to airspace or vertiport capacity. These updates will include inputs from Dynamic Airspace Management and/or Conformance Monitoring (e.g. adherence to feeder fix times).

To ensure UAM vehicle flight efficiency, it will be preferable to hold UAM vehicles on the ground (ground delay) rather than issue an airborne delay. Minor vertiport availability issues (e.g. slightly late departure of a UAM vehicle) will need to be handled tactically by small flight plan adjustments for other UAM vehicles. Certain situations will lead to a reduction in capacity or zero capacity (i.e. no availability).

Vertiport capacity will initially be the greatest limitation to the Flow Management Service. However, in dense operations, airspace and/or route/corridor capacity will also become a limiting factor. To maximise airspace capacity, Flow Management will use 4D trajectories, which will consider vertiport departure and arrival times and be assessed as part of airspace authorisation decisions.

4.4.1 PERFORMANCE EXPECTATIONS/BENEFITS (IN ICAO KPA TERMS)

An effective Flow Management Service enables UAM operations to achieve benefits in the following areas:

- **Safety** - Pre-tactically deconflicts traffic arriving at and departing vertiports and reduces the amount of time in the air through ground-based holding.
- **Environment** - Reduces airborne holding and decreases flight noise, as there will be less of a requirement to hold on approach to a vertiport. Flow Management also minimises the amount of energy that needs to be consumed.
- **Capacity** - Ensures that the greatest capacity is achieved from the available vertiport infrastructure and airspace structure.
- **Flight efficiency** - Minimises the time required to be airborne, thus ensuring that flight efficiency is not impacted by other UAM vehicle movements.
- **Flexibility** - Enables flight plans to be updated as required due to changes in the operational environment.
- **Predictability** - Ensures that a flight plan can be reliably implemented without impact from other UAM vehicle movements.
- **Access and equity** - Ensures that pilots and fleet operators can gain access in a transparent manner to the shared resources of vertiports and airspace.

4.4.2 UATM SERVICE MATURITY PHASES

The following key points summarise the service maturity phases (with further information in the detailed description of the service later in the document):

- The **Horizon 1** Flow Management Service will focus on allocating and adjusting time slots at vertiports for UAM vehicles.
- During **Horizon 2**, as dedicated UAM airspace structures are developed, the Flow Management Service will begin providing pre-tactical Flow Management based on flight requests, capacity constraints and resource availability. Once Conformance Monitoring Services or Dynamic Airspace Management Services are available, tactical traffic Flow Management will be provided.
- By the end of **Horizon 2**, or in **Horizon 3**, Flow Management for ATM and low-level airspace should be integrated to maximise airspace efficiency.
4.5 DYNAMIC AIRSPACE MANAGEMENT SERVICE

The objective of the Dynamic Airspace Management Service is to maximise the performance of low-level airspace and its structures as environmental and operational needs shift. The service also aims to be responsive to ATM needs during nominal and off-nominal scenarios.

Airspace and route/corridor availability for UAM operations will vary for a number of reasons. Furthermore, changes to airspace availability will be variously predictable and unpredictable. Flight Planning and Authorisation and Flow Management decisions will need to be based upon known airspace and route/corridor availability. Following changes in airspace and/or route/corridor availability, existing authorisations, including those already in flight, must be reviewed to determine how the changes affect the flight plans and whether the existing flight authorisations need to be cancelled or amended.

Dynamic routes/corridors can:

- provide strategic segregation of aircraft, increasing available capacity;
- share aircraft noise to prevent concentration over one community; and
- ensure business continuity for fleet operators and vertiports.

When there are changes to the availability of airspace structures, procedures will be needed to ensure that safety is appropriately managed throughout the change.

4.5.1 PERFORMANCE EXPECTATIONS/BENEFITS (IN ICAO KPA TERMS)

An effective Dynamic Airspace Management Service enables UAM operations to achieve benefits in the following areas:

- **Safety** - Minimises airspace safety risk by controlling airspace access.
- **Environment** - Provides a mechanism for noise sharing through the use of alternative routes/corridors.
- **Capacity** - Enables additional routes/corridors and airspace to be made available to increase capacity.
- **Flight efficiency** - Ensures that the most efficient routes/corridors can be made available where possible, even if not in an ongoing manner.
- **Flexibility** - Allows airspace that otherwise would have to remain reserved if it could not be made available dynamically to be used periodically.
- **Predictability** - Provides a system for identifying what airspace is available at what time. Supports business continuity for vertiports, fleet operators and their customers, despite airspace changes.
- **Access and equity** - Ensures the greatest possible availability of airspace whilst enabling prioritisation of airspace access.

4.5.2 UATM SERVICE MATURITY PHASES

The following key points summarise the Service maturity phases (with further information in the detailed description of the Service later in the document):

- During **Horizon 1**, Dynamic Airspace Management will be limited to the promulgation of broad airspace restrictions. Dynamic elements of traffic management in Horizon 1 will be focused on procedures being available (or not) for use by UAM vehicles as defined by ATM.
- During **Horizon 2**, Dynamic Airspace Management will be more holistically implemented. Initially, Dynamic Airspace Management will predominantly focus on the use of pre-defined airspace structures.
- Advances in automation are expected to enable Dynamic Airspace Management to develop new airspace structures in real time, or near-real time, to minimise disruption to or deviation from existing flight plans. This will likely be implemented in a mature **Horizon 2** or **Horizon 3**.
4.6 CONFORMANCE MONITORING SERVICE

The objective of the Conformance Monitoring Service is to identify non-conforming vehicles that impact low-level airspace operations and to ensure timely triggers and mitigation responses for impacted UAM vehicles. This data will also support the systemic review and analysis of UAM operational performance.

The Conformance Monitoring Service ensures that all UAM vehicles in the low-level airspace are in compliance with the flight plan contained in the flight authorisation. In addition to monitoring flight compliance within a route/corridor, the service will also identify UAM vehicles that are not in compliance with a 4D trajectory. Accountability for compliance will lie with pilots and UAM vehicle operators. The Conformance Monitoring Service serves as an additional means of ensuring safety and mitigating risks to UAM operations. Communications with a vehicle will be initiated when non-compliance is predicted and/or detected.

Vehicle non-compliance with a 4D trajectory may have a negative impact on the safety and efficiency of the UATM system. Higher levels of assurance of operational compliance can be achieved through the Conformance Monitoring Service. Data from this service supports both tactical decisions and systemic performance analysis.

4.6.1 PERFORMANCE EXPECTATIONS/BENEFITS (IN ICAO KPA TERMS)

An effective Conformance Monitoring Service enables UAM operations to achieve benefits in the following areas:

- Safety - Real-time and systemic awareness of operations that could impact the safety of the low-level airspace environment.
- Efficiency - Known historical use of airspace provides information to assist in improving future use.

4.6.2 UATM SERVICE MATURITY PHASES

The following key points summarise the Service maturity phases (with further information in the detailed description of the Service later in the document):

- During Horizon 1, Conformance Monitoring will rely on currently available ATM CNS capability as well as ATM and regulatory reporting mechanisms. Onboard UAM vehicle systems will be able to collect and disseminate additional information that can be used to inform Conformance Monitoring. However, a data collection system will need to be implemented.
- In Horizon 2, Conformance Monitoring will provide an ongoing set of information to manage the operational safety risk of UAM operations.
- In Horizon 3, Conformance Monitoring will be important in resolving conflicts between manned and autonomous operations.
USE CASES ARE BASED UPON A MATURE HORIZON 2 IMPLEMENTATION OF THE UATM SERVICES AND IDENTIFY THE SERVICES USED IN EACH PHASE OF FLIGHT.
### 4.7 USE CASES

This section describes two uses cases:

- A generic use case involving a UAM flight from a Central Business District (CBD) vertiport that is not in controlled airspace to a vertiport located close to an airport that is in controlled airspace.
- A location-specific use case based on a flight in Victoria, Australia.

Both use cases are based upon a mature Horizon 2 implementation of the UATM Services and identify the Services used in each phase of flight.

#### 4.7.1 GENERIC USE CASE

Throughout the use case, all data is shared with UATM stakeholders through the Information Exchange Service. At any time, should there be a requirement for a change in vertiport, airspace or route/corridor availability, the Dynamic Airspace Management Service will update the data used by the Flow Management Service.

**PRE-FLIGHT**


- The fleet operator submits a flight request to the Flight Planning and Authorisation Service via the Information Exchange Service. The flight request includes a defined departure time for a flight from a CBD vertiport outside controlled airspace to a vertiport located near the airport within controlled airspace.
- The Flight Planning and Authorisation Service determines a 4D trajectory and flight plan that deconflicts the flight with other planned flights. It takes into consideration restrictions defined by the Flow Management and Dynamic Airspace Management Services and any other applicable rules. This ensures that key performance areas are considered, including airspace capacity, access and equity and environmental impact.
- The fleet operator receives a flight plan and flight authorisation from the Flight Planning and Authorisation Service via the Information Exchange Service.
- The Flight Planning and Authorisation Service reserves FATOs at departure and arrival vertiports.
- The fleet operator uses the Information Exchange Service to obtain pre-flight information (e.g. destination vertiport status, weather and Notice to Airmen [NOTAM]) and prepares a briefing pack for the UAM vehicle pilot.
- The UAM vehicle pilot reviews the briefing pack, accepts the flight plan (via the Information Exchange Service) and makes relevant checks to ensure the dependability of the flight (e.g. battery level).
- The Flight Planning and Authorisation Service receives a message (via the Information Exchange Service) indicating that the UAM pilot has accepted the flight plan.
- The Flow Management Service continually monitors the status of the low-level airspace in case any tactical changes to flight plans and flight authorisations are necessary before departure.
- Passengers board the UAM vehicle.

**DEPARTURE**


- The UAM vehicle pilot departs at the designated time via the vertiport departure path to join the UAM route in uncontrolled airspace in line with the flight plan.
- The Conformance Monitoring Service continually confirms that the UAM vehicle is complying with its 4D trajectory, using information received via the Information Exchange Service.
- The Flow Management Service continually confirms that no changes in the UAM environment will impact the flight plan, using information received via the Information Exchange Service.
EN ROUTE


- The UAM pilot follows the UAM route towards the UAM corridor access point for controlled airspace in line with the flight plan.
- The UAM vehicle enters the UAM corridor and tracks toward the arrival vertiport in line with the flight plan.
- The Information Exchange Service continually updates any changes to the operating environment, including weather and status of the destination vertiport.
- The Conformance Monitoring Service continually confirms that the UAM vehicle is complying with its 4D trajectory, using information received via the Information Exchange Service.
- The Flow Management Service makes minor flight plan adjustments based on minor deviations identified by the Conformance Monitoring Service.
- The Dynamic Airspace Management Service continually confirms that no changes in the UAM environment (e.g. airspace and FATO availability) will impact the flight plan.

APPROACH AND LANDING

**Services** - Airspace and Procedure Design, Information Exchange, Flight Management, Conformance Monitoring

- The UAM vehicle pilot transitions from cruise via the vertiport arrival path to land at the reserved vertiport FATO in line with the flight plan.
- The Conformance Monitoring Service continually confirms that the UAM vehicle is complying with its 4D trajectory, using information received via the Information Exchange Service.
- The UAM vehicle pilot taxis to the stand and the fleet operator is informed that the flight has terminated safely via the Information Exchange Service.
- The flight plan closes and relevant stakeholders are informed via the Information Exchange Service.
- Passengers disembark the UAM vehicle.

OFF-NOMINAL SITUATIONS

If the Flow Management Service, in coordination with the Dynamic Airspace Management Service, identifies a change in the UAM environment that will impact the flight plan, a new flight plan will be issued to the UAM vehicle pilot via the Information Exchange Service. Changes in the UAM environment can include unplanned Dynamic Airspace Management updates and reserved FATO unavailability.

If the Conformance Monitoring Service identifies (via the Information Exchange Service) that the UAM vehicle is not complying with its 4D trajectory,

- an alert will be issued to the UAM pilot via the Information Exchange Service, and
- alerts and alternative flight plans will be issued to other UAM pilots as necessary (through the Flow Management Service and Flight Plan and Authorisation Service via the Information Exchange Service).

4.7.2 LOCATION-SPECIFIC USE CASE - VICTORIA, AUSTRALIA

This section describes the application of UATM to a real low-level airspace environment, specifically the airspace around Melbourne, Victoria in Australia. The airspace around Melbourne already has a large number of airspace structures and procedures to enable current aviation operations (Figure 7).
Figure 7: Airspace near Melbourne, Victoria, Australia, Taken from the Melbourne Visual Terminal Chart

There are a number of challenges when flying in the low-level airspace near Melbourne, including the operation of Essendon Airport, which is located between Melbourne Airport and the Melbourne CBD. Essendon airport has a dynamic flow of aircraft, including a large mix of IFR and VFR aircraft, emergency services operations and both fixed-wing and rotor aircraft.
In addition to this, in the future, new parallel runway operations at Melbourne Airport are expected to have a significant impact on how the airspace operates. Other smaller changes in the Melbourne airspace will also have an impact, such an expected increase in flight training activity around Avalon Airport.

This hypothetical location-specific example considers a mature Horizon 2 use case of a UAM operation flying from Geelong to Melbourne Airport. No detailed airspace and procedure design has yet been undertaken for this use case.

Building on the generic use case, the departure, en route, approach and landing phases of the flight include the following location-specific elements:

- The flight departs from a dedicated vertiport in Geelong in accordance with an authorised flight plan provided by the Flight Planning and Authorisation Service. The flight plan routes the UAM operation into two stages: (1) from Geelong to the Melbourne CBD, and then (2) between the CBD and Melbourne Airport.
- Between Geelong and Melbourne CBD, there is Avalon Airport, which is a towered aerodrome. Avalon Tower has controlled airspace that facilitates scheduled flights and airline jet training in addition to GA flight training activity.
- The route issued between Geelong and the Melbourne CBD is to track via Port Philip Bay as defined by the Airspace and Procedures Design Service. This route demonstrates some of the operational complexities as well as over-water flight considerations:
  - The route can largely remain outside of controlled airspace. This minimises the ATC and pilot workload through minimising entry/exit points for controlled airspace around Avalon Airport, which can be avoided entirely.
  - The route remains clear of general aviation flight training activity to the west of Avalon, which occurs outside controlled airspace.
  - The route minimises overflight of noise-sensitive communities.
  - The route, however, crosses the coastal VFR lane between Altona and Carrum.
- There is a combination of danger and restricted areas at St Leonards, Port Philip Bay and Point Cook. The availability of UAM routes (defined by the Airspace and Procedure Design Service) may vary if the danger and/or restricted areas are active as defined by the Dynamic Airspace Management Service. The Flight Planning and Authorisation Service will use routes that are planned to be available.
- A key point currently for VFR traffic on arrival from Port Philip Bay to Melbourne CBD (prior to entering controlled airspace) is Station Pier used by the Flight Planning and Authorisation Service in flight planning.
- The coastal VFR lane between Altona and Carrum is heavily trafficked and crosses Station Pier, facilitating general aviation flow outside of controlled airspace. This may require UAM specific procedures to safely integrate with the traffic flow as defined by Airspace & Procedures Design, Flow Management and Information Exchange Services.
- Airspace between the CBD and Melbourne Airport is controlled due to the high volume of traffic movements at Melbourne and Essendon airports.
- To transit from the CBD to Melbourne Airport, a UAM corridor is used. Through controlled airspace, the UAM operation is segregated from both Melbourne Airport and Essendon arrivals and departures through the Airspace and Procedures Design Service.
- All flights travelling from Geelong to Melbourne Airport will need to be sequenced with flights from Melbourne CBD as they would both use the same corridor between the CBD and Melbourne Airport. The required airspace structures will be defined in the Airspace and Procedure Design Service and sequencing will be determined by the Flight Planning and Authorisation and Flow Management Services.
- The available corridors between the CBD and Melbourne Airport may vary depending on weather conditions, the runway modes in use and the traffic situation at both Melbourne and Essendon airports. The airspace structures will be defined by the Airspace and Procedure Design Service and routing planned using the Flight Planning and Authorisation and Dynamic Airspace Services.
- The flight approaches and lands at a dedicated vertiport at Melbourne Airport in accordance with an authorised flight plan defined by the Flight Planning and Authorisation Service.
VICTORIAN UAM OPERATIONS - PREPARATION AND LAUNCH

As part of the CONOPS development work, simulation and analysis were undertaken to commence validation of the concepts. The simulation and analysis activities completed to date are described in more detail in Annex C. Analysis of these simulations has identified that, in some locations, current ATM concepts will quickly become insufficient for managing new UAM operations. In addition, results indicate that UATM Services have safety, flight efficiency, capacity and predictability benefits.

Ongoing operations research and modelling will continue following the publication of this CONOPS. This research will inform the development of services so that they are implemented at the appropriate time to ensure safety, capacity, and efficiency of the overall network. As part of design validation, CRM may be used to determine the safety risk associated with the location of proposed routes or corridors. Work has commenced to examine the collision risk of aircraft operations in combination with UAM operations in Melbourne (Figure 8). The evolution of this conflict risk modelling will inform future corridor and route design activities.

Figure 8: A Contour Map of Collision Risk in Melbourne, Australia
The priority for enabling UAM operations will be establishing the foundational airspace and procedures designs. This is the most significant activity in terms of resources and time required to progress. Airspace and procedure design activities will involve the following:

- Further simulation and risk modelling to identify trigger points (e.g. airspace capacity or complexity points) that signal transition from Horizon 1 to Horizon 2 (e.g. identifying where and when the Flow Management Service will need to come online);
- Assessment of airspace classification and airspace volumes to support UAM operations as appropriate for Australia;
- Definition of flight rules to support scaled operations in IMC;
- Definition of required navigation performance, and requirements for performance-based communications and surveillance;
- Definition of airspace corridors and procedure protection areas; and
- Defined aircraft performance categories applicable to UAM vehicles.

In addition, developing the necessary components of the Information Exchange Service will require significant lead time. These activities include the following:

- Creating aeronautical information management (AIM) standards for UAM operations in low-level airspace,
- Developing potential new UAM airspace or route classifications, and
- Developing digital data sets in addition to the currently published Australian Aeronautical Information Publication (AIP) product groups.

From Day 1 of UAM operations in Victoria, it will be reasonable to expect that the following Service components will be available:

- Airspace and Procedures Design
  - Letter of Agreement (LOA) established between Melbourne and Essendon towers to handle the coordination of UAM vehicles between Melbourne CBD and Melbourne Airport to allow for a more seamless transfer of UAM vehicles within the Melbourne control zone.
- Information Exchange
  - To the extent that existing CNS systems are relied upon, increased coverage of CNS systems (i.e. additional ADS-B receivers and Very High Frequency [VHF] transceivers), which may support Conformance Monitoring Services, in and around the Melbourne CBD;
  - A cloud-based vertiport reservation system;
  - UAM operations information (i.e. vertiport location/facility) and additional charting products/education material via Australian AIP; and
  - A weather information service tailored to UAM in addition to existing sets as obtained by the Australian Bureau of Meteorology/National Aeronautical Information Processing System (NAIPS).
- Conformance Monitoring
- Noise abatement procedures that are specific to UAM operations with respect to the populated areas of Melbourne and its surrounding areas;
- Data collection of actual operational UAM vehicle performance from both a CNS and a noise perspective; and
- Promulgation of UAM operations of interest to communities (e.g. an online aircraft noise information portal such as WebTrak), describing trends and patterns of UAM operations.
SECTION 5
ACRONYMS AND GLOSSARY

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5.2 Glossary of terms 47
## 5 ACRONYMS AND GLOSSARY

### 5.1 ACRONYMS

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<th>DEFINITION</th>
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<tr>
<td>ADC</td>
<td>Aerodrome Controller</td>
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<tr>
<td>ADS-B</td>
<td>Automatic Dependent Surveillance-Broadcast</td>
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<tr>
<td>AFIS</td>
<td>Aerodrome Flight Information Service</td>
</tr>
<tr>
<td>AGL</td>
<td>Above Ground Level</td>
</tr>
<tr>
<td>AIM</td>
<td>Aeronautical Information Management</td>
</tr>
<tr>
<td>AIP</td>
<td>Aeronautical Information Publication</td>
</tr>
<tr>
<td>AIS</td>
<td>Aeronautical Information Service</td>
</tr>
<tr>
<td>AMSL</td>
<td>Above Mean Sea Level</td>
</tr>
<tr>
<td>ANSP</td>
<td>Air Navigation Service Provider</td>
</tr>
<tr>
<td>API</td>
<td>Application Programming Interface</td>
</tr>
<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
</tr>
<tr>
<td>ATM</td>
<td>Air Traffic Management</td>
</tr>
<tr>
<td>CASA</td>
<td>Civil Aviation Safety Authority</td>
</tr>
<tr>
<td>CBD</td>
<td>Central Business District</td>
</tr>
<tr>
<td>CIS</td>
<td>Common Information Service</td>
</tr>
<tr>
<td>CNS</td>
<td>Communications, Navigation and Surveillance</td>
</tr>
<tr>
<td>CONOPS</td>
<td>Concept of Operations</td>
</tr>
<tr>
<td>CRM</td>
<td>Collision Risk Modelling</td>
</tr>
<tr>
<td>D-ATIS</td>
<td>Digital Automatic Terminal Information Service</td>
</tr>
<tr>
<td>D-MET</td>
<td>Digital Meteorological Service</td>
</tr>
<tr>
<td>D-NOTAM</td>
<td>Digital Notice to Airmen</td>
</tr>
<tr>
<td>eVTOL</td>
<td>Electric Vertical Take-off and Landing vehicle</td>
</tr>
<tr>
<td>FAA</td>
<td>Federal Aviation Administration</td>
</tr>
<tr>
<td>FATO</td>
<td>Final Approach and Take-off area</td>
</tr>
<tr>
<td>FIMS</td>
<td>Flight Information Management System</td>
</tr>
<tr>
<td>GA</td>
<td>General Aviation</td>
</tr>
<tr>
<td>ICAO</td>
<td>International Civil Aviation Organisation</td>
</tr>
<tr>
<td>IFR</td>
<td>Instrument Flight Rules</td>
</tr>
<tr>
<td>IMC</td>
<td>Instrument Meteorological Conditions</td>
</tr>
<tr>
<td>KPA</td>
<td>Key Performance Area</td>
</tr>
<tr>
<td>LOA</td>
<td>Letter of Agreement</td>
</tr>
<tr>
<td>ACRONYM</td>
<td>DEFINITION</td>
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<tr>
<td>-----------</td>
<td>----------------------------------------------------------------</td>
</tr>
<tr>
<td>MET</td>
<td>Meteorological</td>
</tr>
<tr>
<td>NAA</td>
<td>National Airworthiness Authority</td>
</tr>
<tr>
<td>NAIPS</td>
<td>National Aeronautical Information Processing System</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>NASA-TLX</td>
<td>National Aeronautics and Space Administration-Task Load Index</td>
</tr>
<tr>
<td>NOTAM</td>
<td>Notice to Airmen</td>
</tr>
<tr>
<td>NM</td>
<td>Nautical Mile</td>
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<tr>
<td>PBN</td>
<td>Performance-based Navigation</td>
</tr>
<tr>
<td>RNAV</td>
<td>Area Navigation</td>
</tr>
<tr>
<td>RNP</td>
<td>Required Navigation Performance</td>
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<tr>
<td>RNP-AR</td>
<td>Required Navigation Performance Authorisation Required</td>
</tr>
<tr>
<td>RPA</td>
<td>Remotely Piloted Aircraft</td>
</tr>
<tr>
<td>RPAS</td>
<td>Remotely Piloted Aircraft System</td>
</tr>
<tr>
<td>RPT</td>
<td>Regular Public Transport</td>
</tr>
<tr>
<td>SAR</td>
<td>Search and Rescue</td>
</tr>
<tr>
<td>SART</td>
<td>Situation Awareness Rating Technique</td>
</tr>
<tr>
<td>SMC</td>
<td>Surface Movement Controller</td>
</tr>
<tr>
<td>TAAM</td>
<td>Total Airspace and Airport Modeller</td>
</tr>
<tr>
<td>TFR</td>
<td>Temporary Flight Restriction</td>
</tr>
<tr>
<td>TRA</td>
<td>Temporary Restricted Airspace</td>
</tr>
<tr>
<td>UAM</td>
<td>Urban Air Mobility</td>
</tr>
<tr>
<td>UAS</td>
<td>Unmanned Aircraft System</td>
</tr>
<tr>
<td>UASP</td>
<td>Urban Airspace Service Provider</td>
</tr>
<tr>
<td>UATM</td>
<td>Urban Air Traffic Management</td>
</tr>
<tr>
<td>USP</td>
<td>UTM Service Provider</td>
</tr>
<tr>
<td>USS</td>
<td>UAS Service Supplier</td>
</tr>
<tr>
<td>UTM</td>
<td>Unmanned Aircraft System Traffic Management</td>
</tr>
<tr>
<td>VFR</td>
<td>Visual Flight Rules</td>
</tr>
<tr>
<td>VHF</td>
<td>Very High Frequency</td>
</tr>
<tr>
<td>VLOS</td>
<td>Visual Line-of-Sight</td>
</tr>
<tr>
<td>VTOL</td>
<td>Vertical Take-off and Landing vehicle</td>
</tr>
</tbody>
</table>
5.2 GLOSSARY OF TERMS

5.2.1 ICAO KEY PERFORMANCE AREAS


ACCESS AND EQUITY

A global air navigation system should provide an operating environment that ensures that all airspace users have the right of access to ATM resources needed to meet their specific operational requirements, and ensures that the shared use of the airspace for different airspace users can be achieved safely. The global air navigation system should ensure equity for all airspace users that have access to a given airspace or service. Generally, the first aircraft ready to use the ATM resources will receive priority, except where significant overall safety or system operational efficiency would accrue or national defence considerations or interests dictate by providing priority on a different basis.

CAPACITY

The global air navigation system should exploit the inherent capacity to meet airspace user demand at peak times and locations while minimizing restrictions on traffic flow. To respond to future growth, capacity must increase, along with corresponding increases in efficiency, flexibility, and predictability while ensuring that there are no adverse impacts to safety giving due consideration to the environment. The air navigation system must be resilient to service disruption and the resulting temporary loss of capacity.

COST EFFECTIVENESS

The air navigation system should be cost effective, while balancing the varied interests of the ATM community. The cost of service to airspace users should always be considered when evaluating any proposal to improve ATM service quality or performance. ICAO guidelines regarding user charge policies and principles should be followed.

EFFICIENCY

Efficiency addresses the operational and economic cost effectiveness of gate-to-gate flight operations from a single-flight perspective. Airspace users want to depart and arrive at the times they select and fly the trajectory they determine to be optimum in all phases of flight.

ENVIRONMENT

The air navigation system should contribute to the protection of the environment by considering noise, gaseous emissions, and other environmental issues in the implementation and operation of the global air navigation system.

FLEXIBILITY

Flexibility addresses the ability of all airspace users to modify flight trajectories dynamically and adjust departure and arrival times thereby permitting them to exploit operational opportunities as they occur.

GLOBAL INTEROPERABILITY

The air navigation system should be based on global standards and uniform principles to ensure the technical and operational interoperability of air navigation systems and facilitate homogeneous and non-discriminatory global and regional traffic flows.

PARTICIPATION BY THE ATM COMMUNITY

The ATM community should continuously be involved in the planning, implementation, and operation of the system to ensure that the evolution of the global air navigation system meets the expectations of the community.

PREDICTABILITY

Predictability refers to the ability of the airspace users and air navigation service providers to provide consistent and dependable levels of performance. Predictability is essential to airspace users as they develop and operate their schedules.

SAFETY

Safety is the highest priority in aviation, and ATM plays an important part in ensuring overall aviation safety. Uniform safety standards and risk and safety management practices should be applied systematically to the air navigation system. In implementing elements of the global aviation system, safety needs to be assessed against appropriate criteria, and in accordance with appropriate and globally standardized safety management processes and practices.
SECURITY
Security refers to the protection against threats, which stem from intentional (e.g. terrorism) or unintentional (e.g. human error, natural disaster) acts affecting aircraft, people or installations on the ground. Adequate security is a major expectation of the ATM community and of citizens. The air navigation system should therefore contribute to security and should be protected against security threats. Security risk management should balance the needs of the members of the ATM community who require access to the system with the need to protect the air navigation system. In the event of threats to aircraft or threats using aircraft, ATM shall provide responsible authorities with appropriate assistance and information.

5.2.2 UNMANNED AIRCRAFT SYSTEMS TRAFFIC MANAGEMENT TERMS
Source: ICAO. Unmanned aircraft systems traffic management (UTM) – A common framework with core principles for global harmonization (2nd ed.).
* denotes a formally recognised ICAO definition

C2 LINK
The data link between the remotely piloted aircraft and the remote pilot station for the purpose of managing the flight.

DETECT AND AVOID*
The capability to see, sense or detect conflicting traffic or other hazards and take the appropriate action.

GEOFENCE
A virtual three-dimensional perimeter around a geographic point, either fixed or moving, that can be predefined or dynamically generated and that enables software to trigger a response when a device approaches the perimeter (also referred to as geowarning or geocaging).

REMOTELY PILOTED AIRCRAFT (RPA)*
An unmanned aircraft which is piloted from a remote pilot station.

REMOTELY PILOTED AIRCRAFT SYSTEM (RPAS)*
A remotely piloted aircraft, its associated remote pilot station(s), the required C2 Link and any other components as specified in the type design.

SEGREGATED AIRSPACE*
Airspace of specified dimensions allocated for exclusive use to a specific user(s).

UNMANNED AIRCRAFT SYSTEM TRAFFIC MANAGEMENT (UTM)
A specific aspect of air traffic management which manages UAS operations safely, economically and efficiently through the provision of facilities and a seamless set of services in collaboration with all parties and involving airborne and ground-based functions.

UNMANNED AIRCRAFT SYSTEM TRAFFIC MANAGEMENT (UTM) SYSTEM
A system that provides UTM through the collaborative integration of humans, information, technology, facilities and services, supported by air, ground or space-based communications, navigation and surveillance.

UNMANNED AIRCRAFT SYSTEM (UAS)*
An aircraft and its associated elements which are operated with no pilot on board.

VISUAL LINE-OF-SIGHT (VLOS) OPERATION*
An operation in which the remote pilot or RPA observer maintains direct unaided visual contact with the remotely piloted aircraft.
## ANNEX A

### ROLES AND RESPONSIBILITIES

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<td>UAS Service Supplier (USS) / UTM Service Provider (USP)</td>
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<td>National Airworthiness Authority</td>
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<tr>
<td>Other Authorities/Regulators</td>
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</table>
A. ROLES AND RESPONSIBILITIES

A.1 UAM VEHICLE PILOT

UAM vehicles are expected initially to be controlled by a pilot on board. In the future, some UAM vehicles will include a remote, ground-based pilot who is in command of a single or multiple UAM vehicles once the appropriate standards and certification criteria are defined. At some point, the term pilot may no longer be applicable and other terms such as monitoring pilot or supervisor may be used. Some UAM vehicles are expected to achieve full autonomy at a point in the future. The UAM environment will include a mix of piloting mechanisms that include onboard pilot and autonomous operation.

A.2 VERTIPORT OPERATOR

A vertiport operator will define what services their vertiport will provide and to whom those services will be provided (in consultation with regulators). Vertiport operators will be responsible for ground operations at the vertiport. The vertiport operator will contribute to the development of rules for vertiport availability and priority given to specific fleet operators or mission type (e.g. scheduled operations).

Vertiport operators will be responsible for overseeing ground safety, security and boarding procedures and charging or refuelling, although this responsibility could sit with fleet operators or other third parties. The vertiport operator will provide information regarding the operating status of their vertiport, including the availability of FATOS, stands (where applicable), personnel and fuel (e.g. electricity).

A.3 FLEET OPERATOR

Fleet operators will manage their respective UAM vehicle operations. Fleet operators will receive orders for flights through a booking platform operator for on-demand or timetabled bookings. The fleet operator will be responsible for selecting the vehicle and pilot for incoming ride requests.

In coordination with the UAM vehicle pilot, the fleet operator will submit a flight intent notification for the operations. In coordination with the UAM vehicle pilot, the fleet operator will be responsible for final acceptance of a flight plan.

The fleet operator will provide real-time information regarding the operating status of their UAM vehicles.

A.4 BOOKING PLATFORM OPERATOR

The booking platform will provide the interface for trip requests from customers and will connect the request with the fleet operator. The booking platform operator will consider different vertiports for operating the flight. Options under consideration will include arrival and/or departure from different vertiports and connection with other transport mechanisms.

A.5 AIR NAVIGATION SERVICE PROVIDER

An ANSP provides air navigation services on behalf of a company, region, or country. Depending on the specific mandate, an ANSP provides one or more of the following services to airspace users:

- ATM services
- CNS systems
- Meteorological (MET) services for air navigation
- Search and rescue (SAR) services
- AIM.

In some nations, the ANSP will accommodate UAM operations through the provision of ATM and/or other services. The roles and responsibilities of the traffic management authority for the UAM environment will be executed by the ANSP or delegated to an industry organisation or organisations. This decision to centralise or decentralise services will vary between countries. It is expected that at least some services will be provided by a centralised organisation.

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14 This organisation could be termed the Urban Airspace Service Provider (UASP)
A.6 UAS SERVICE SUPPLIER (USS) / UTM SERVICE PROVIDER (USP)

UAM operations are expected to integrate into the low-level airspace where drones operate. Therefore, any systems used for UATM will need to exchange information with a USS or USP, which are key roles in UTM. In addition, some services that are provided by USSs will be adopted for UATM.

A USS/USP\(^{15}\) is the customer-facing component of the UTM ecosystem, providing traffic management services to UAS operators in low-level airspace. A USS will act as a communication bridge between an ANSP and UAS operator when necessary. The USS will be an industry or government organisation(s) delegated or approved by the National Airworthiness Authority (NAA) or be executed directly by the ANSP, depending on each nation’s policy or their implementation of UTM and regulatory arrangements.

It is highly likely that in many nations, multiple USSs will serve UAS operators in the same geographical region. It is likely that every USS will interface with a centralised, government-owned or -controlled UTM sub-system, often referred to as a Flight Information Management System (FIMS) or Common Information Service (CIS)\(^{17}\) to ensure safety, integrity, oversight and security.

A USS will receive real-time information regarding airspace constraints and intentions of other aircraft available through ANSPs\(^{18}\). A USS will provide some UTM services that are typically only provided by ANSPs in manned aviation, including but not limited to strategic deconfliction and conformance monitoring for UAS operations.

The primary means of communication and coordination between the ANSP(s), USSs, operators and other stakeholders will be through a distributed network of machine-to-machine Application Programming Interfaces (APIs), and not between pilots and air traffic controllers via voice communication.

A.7 NATIONAL AIRWORTHINESS AUTHORITY

The role of the NAA will be the same as for the aviation system as a whole. Specifically with respect to UATM, the NAA will be responsible for certification of all elements that are considered to be safety-related. In many cases, the certification requirements for either non-existent or in-development traffic management systems are yet to be defined.

A.8 OTHER AUTHORITIES/REGULATORS

Given the impact of UAM on noise in the urban environment, it will be important to ensure that the roles with respect to aircraft noise management are clearly defined. Each country will have different organisations responsible for noise management in low-level airspace. Land planning authorities will have defined roles with respect to vertiports.

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\(^{15}\) Federal Aviation Administration (FAA). (2020). Unmanned aircraft system (UAS) traffic management (UTM) concept of operations v. 2.0.

\(^{16}\) USS and USP can be used interchangeably. In this CONOPS, the term, USS, is used.

\(^{17}\) In nearly all national UTM implementations examined, the ANSP is the owner and operator of the FIMS/CIS. For the purposes of this CONOPS, the term, FIMS, is used to describe the centralised system interfacing UTM with the ATM.

\(^{18}\) ICAO. (2020). Unmanned Aircraft Systems Traffic Management (UTM) – A common framework with core principles for global harmonization (2nd ed.).
## ANNEX B

CONOPS DETAILED DESCRIPTION

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<td>B.6</td>
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B CONOPS – DETAILED DESCRIPTION

B.1 AIRSPACE AND PROCEDURE DESIGN SERVICE

B.1.1 SERVICE OBJECTIVE

The objective of the Airspace and Procedure Design Service is to create airspace structures and supporting procedures that strategically maximise the performance of the available low-level airspace and minimise any additional impact on existing ATC and piloted operations.

B.1.2 DESCRIPTION

The following sections define the Airspace and Procedure Design Service for all future horizons of UATM.

VERTIPORTS

A transition zone around vertiports will be needed where the UAM vehicle transitions from en route cruise to approach and landing, and from take-off and departure to en route cruise (Figure 9). Design of the transition zone will need to be cognisant of other low-level airspace user requirements (for example, UAS). Airspace structure and procedures for arrival, departure and missed approach paths for vertiport FATOs will be required. The design of arrival, departure and missed approach paths will be impacted by factors including, but not limited to, the following:

- Weather (e.g. requirements for landing and departure into wind)
- Existing infrastructure
- Route structure
- Noise management, including sensitivity to surrounding land uses (e.g. schools)
- eVTOL performance categories (e.g. speed, manoeuvrability, noise, weight)

Development of vertiports may require approval from multiple levels of government and different sets of requirements that impact airspace design around vertiports. Arrival, departure and missed approach paths to vertiports FATOs will require protection from obstacles, traffic and other airspace users to ensure access. Arrival, departure and missed approach paths will have an impact on surrounding infrastructure development, including the development of local alternative vertiports. The airspace surrounding vertiports will need to be protected from external property development or at the least monitored to ensure that arriving and departing aircraft have sufficient unobstructed flight paths (i.e. a prescribed airspace concept).

Entry and exit points around the vertiport transition zone will be required as part of arrival and departure procedures. Types of holding criteria suitable for eVTOLs will be needed at points where UAM vehicles need to wait to enter the transition zone. Airspace procedures will seek to minimise the occupancy time in the transition zone and on the vertiport FATO. Vertiports will require ground procedures for UAM vehicles to transition between stands and FATOs.
Procedures will need to be developed for vertiports with high demand to facilitate safe interactions between arriving and departing aircraft and to manage bottlenecks that will develop around vertiports. The design of holding circuits, transition zones, and arrival, departure, and missed approach paths will, through design, incorporate separation margins from other low-level airspace users.

Airspace procedures will need to support operations in a range of weather conditions matched to, or commensurate with, the weather tolerance capabilities of UAM vehicles. Airspace procedures will need to manage the impact of non-aviation-related UAM issues that occur at the vertiport (e.g. noise or visual-related community perceptions, infrastructure developments).

Contingency procedures will need to be in place to manage the impact of off-nominal situations that occur at the vertiport. Procedures for ground response and airborne UAM vehicle response to emergency scenarios (such as an aircraft accident or disabled aircraft on a FATO) will be required.

CONTROLLED AIRSPACE

UAM operations (initially operating under VFR conditions) will remain outside controlled airspace unless a clearance is given (for example arrival at or transit through controlled tower airspace) to minimise ATM impact on UAM operations, and vice versa. Clearance into controlled airspace will be required (through verbal clearance or some other, possibly predetermined, agreement) under VFR conditions. UAM vehicles will operate similarly to other VFR airspace users in controlled airspace. This includes their level of prioritisation compared to IFR aircraft in accordance with ATC procedures.

In some circumstances, it will not be possible to have certainty of access to controlled airspace (where no dedicated segregated corridor exists) prior to arrival at the airspace. UAM vehicles will need to be able to hold at or near points where they want to enter controlled airspace in a similar manner to other airspace users.

UAM corridors in controlled airspace, which are solely for the use of UAM traffic that is segregated from other airspace users, could allow UAM vehicles to transit through controlled airspace with a reduced burden on ATC (Figure 10). Dedicated airspace structures (such as UAM corridors) and procedures in controlled airspace will reduce the level of interaction with ATC, thereby reducing the potential ATC workload driven by UAM. Corridors will help reduce the impact of prioritisation of IFR over VFR flights.

ATM will need to optimise its use of airspace around airports so that UAM vehicles are segregated but able to access a vertiport close to the airport. Close to an airport, individual UAM corridors will need to be opened or closed based on the active airport runway mode. Defined procedures for flight notification times before a UAM vehicle departs a vertiport in or near controlled airspace will be necessary.

19 Hovering or orbiting.
UNCONTROLLED AIRSPACE (CLASS G)
UAM vehicles will be able to fly in uncontrolled airspace in a manner similar to other airspace users. Routes (dedicated to UAM or used by UAM and other airspace users) will reduce the likelihood of close-proximity safety occurrences with other airspace users, controlled flight into terrain, and ground obstacle collision safety occurrences (Figure 11).

The growth of UAM operations within a volume of airspace can affect the classification of that airspace (e.g. changes from Class G to D airspace). Alternatively, designating specific UAM airspace (including reclassification of Class G airspace) will reduce the likelihood of close proximity safety occurrences with other airspace users, controlled flight into terrain, and ground obstacle collision safety occurrences.

UAM routes and airspace shall be used where a risk-based profile justifies this and/or where benefits are defined and of value (e.g. collision risk, noise management).

DEDICATED UAM AIRSPACE STRUCTURES, CORRIDORS AND ROUTES
The establishment of UAM operations may require a new class of airspace (for UAM) to be created, including the services required for that airspace. Dedicated airspace structures (including UAM corridors in controlled airspace and UAM routes in uncontrolled airspace) will increase the predictability of UAM vehicle locations, thereby improving situation awareness for all low-level airspace stakeholders.

Dedicated airspace structures will reduce the risk of collision with obstacles and other airspace users. Dedicated airspace, corridors and routes for UAM operations will, as far as is practicable, be designed to support strategic segregation and minimise tactical intervention by ATC.

Due to the higher frequency and density of UAM vehicles climbing and descending compared to traditional aircraft, it is desirable that UAM corridors and routes sit in airspace below where traditional aircraft operate.

Other airspace users and UAM vehicle pilots will need appropriate levels of knowledge and situation awareness of the dedicated airspace, corridors and routes. Dependable information on obstacles, both permanent and temporary, will be needed for the design of airspace, corridors and routes.

Dedicated airspace, corridors and routes will increase the predictability of airspace access for UAM vehicles.

Community impact will be a significant consideration in the design of airspace, corridors and routes.

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20 In alignment with ICAO. (2020). Unmanned Aircraft Systems Traffic Management (UTM) – A common framework with core principles for global harmonization (2nd ed.).
Dedicated airspace, corridors and routes could alleviate concerns regarding community perception (visual or noise emissions) by avoiding sensitive areas (e.g. residential areas, schools), or where this is not feasible, through alternating traffic flows (shared perception). Flexibility in airspace structures (including the periodic opening and closing of routes and corridors) could enable the distribution of some noise and visual impacts.

For the majority of UAM operational locations (e.g. urban/metropolitan), traditional RPT aviation is expected over time to use less low-level controlled airspace (as navigation systems increase in precision) as they transit to or from airports. This will result in more airspace becoming available for UAM operations where UAM vehicles will be transiting to a large variety of destinations. Traditional ATM airspace containment areas will become smaller laterally and the airspace profiles will become shallower vertically to accommodate more efficient and precise aircraft and to support continuous descent operations.

Dedicated UAM airspace structures (including routes and corridors) will need to be usable by UAM vehicle categories with varying performance (e.g. speed) and capability (e.g. performance-based navigation [PBN] precision). A minimum set of capability requirements to use dedicated airspace structures will need to be established to form the basis for procedure/route design standards and separation standards development, which will be vital to UAM being viable once it progresses beyond VFR operations.

Dedicated UAM airspace structures will need to be accessible by non-eVTOL vehicles at times.

Within routes and corridors, it may become necessary to have structures to manage both bi-directional and higher-density traffic. Initial solutions to this may use similar approaches to those currently used for VFR routes.

Airspace structures for UATM and ATM will need to consider the impact of wake turbulence. Consideration of wake turbulence in airspace design will be different in the future compared to current practices where it is not a consideration. The effect of wake turbulence behaviour on new eVTOL designs will also need to be considered.

UATM system and UAM vehicle autonomy will allow for practical use of free-route airspace. However, as the operational tempo and traffic density increase (e.g. around vertiports and controlled airspace initially, or simply due to significant growth in general), airspace structures are more likely to be required.

Airspace structures will need to change as new vertiports are established and as the industry grows.

Airspace structures will be developed with consideration of other users of low-level airspace to ensure equitable airspace access.

**COMMUNICATION, NAVIGATION AND SURVEILLANCE FOR UAM OPERATIONS**

Traditional CNS technologies (e.g. radio transmissions, tuning navigation aids, reporting points) are likely to be replaced over time by newer technologies. However, for the foreseeable future, UATM will continue to use CNS concepts as currently used in ATM (e.g. for separation standards and procedure design standards). New separation and procedure standards will be required to facilitate the full implementation of concepts in this CONOPS.

**PROCEDURES FOR EMERGENCIES AND OFF-NOMINAL OPERATIONS**

Procedures will need to be developed for emergency situations so that all vehicle operators have a consistent understanding of the options and actions necessary to ensure safety. Procedures will need to be developed for medical emergencies so that any medical services and/or resources can be coordinated in a timely manner.

The airspace design will need to allow for alternate landing locations to manage issues at vertiports and on board the UAM vehicle. UAM operations can require an alternate landing site, or sites, during a flight. Alternate landing sites for emergencies and off-nominal operations can potentially include vertiports, helicopter landing sites, or defined suitable forced landing areas.
B.1.3 CHALLENGES WITH CURRENT OPERATIONAL CAPABILITY

The following challenges to implementing the Airspace and Procedure Design Service with current operational capability have been identified:

- VHF radio coverage can be poor in areas used by UAM vehicles for voice communications, within both controlled and uncontrolled airspace.
- Existing surveillance coverage can be poor in areas used by UAM vehicles, within both controlled and uncontrolled airspace.
- The resolution of existing surveillance systems will be insufficient to deal with traffic density in built-up areas.
- Procedures for entering controlled airspace will need to be redesigned to manage the performance capabilities of UAM vehicles and to increase capacity.
- High-density IMC operations that service urban environments would be severely limited by the use of current IFR procedure design standards due to the underlying assumptions used in current separation standards.
- Some airports will allow UAM aircraft to use runways when there is no dedicated helicopter landing area, or in IMC conditions. However, this will not be practical for reliable, busy operations.
- Using currently applicable separation tolerances and associated protection areas from a single procedure could envelop large portions of the city, restricting simultaneous operations to multiple vertiports in close proximity.
- The associated approach minima derived for an instrument flight procedure will also be of little operational benefit for vertiports as the standards have been developed for a traditional airport environment rather than vertiports nestled amongst significant vertical obstructions typical of an urban environment.
- While the impact of these shortcomings would be minimal in the initial phases of operations, it will become a determining factor in the viability of the concept transitioning to operations in IMC in a high-traffic-density environment.

B.1.4 PERFORMANCE EXPECTATIONS (IN ICAO KPA TERMS)

An effective Airspace and Procedure Design Service enables UAM operations to achieve benefits in the following areas:

- **Safety** - Strategic segregation and/or separation of UAM aircraft from other types of aircraft, other eVTOLs and on-ground obstacles; reduced workload for ATC in managing UAM aircraft.
- **Environment** - The ability to position routes over less noise-sensitive areas (e.g. highways, train tracks, rivers).
- **Capacity** - Vertiport airspace design and procedures, which will maximise the capacity of the vertiport while maintaining appropriate levels of safety, noise, privacy and other risks or impacts.
- **Flight efficiency** - Increased efficiency due to the reduced likelihood of conflicting traffic.
- **Flexibility** - Provision of flexibility when traffic loads need to be dissipated to ensure operational continuity and/or efficiency of traffic flow.
- **Predictability** - Knowledge of where UAM vehicles can fly and increased likelihood of airspace access.
- **Access and equity** - Greater access to controlled airspace through the use of dedicated airspace structures and routes.
- **Participation and collaboration** - Provision of a structured means by which new vertiport infrastructure can be considered.
- **Global interoperability** - Standardised structures and procedures for the UAM industry used in different countries.

B.1.5 UATM SERVICE MATURITY PHASES

**HORIZON 1**

During Horizon 1, initial eVTOL operations will use existing airspace structures and procedures, or new structures and procedures that use existing ATM concepts. At this time, UAM vehicles will need to request airspace clearance to access controlled airspace or have agreements in place that enable predefined clearance parameters. These ATM practices will operate in the same manner as for other types of aircraft. Airspace access would be through the application of existing equity principles and priority processes: i.e. UAM aircraft cannot expect guaranteed access or priority.
Certain operating conditions would be extremely challenging to implement, including the following:

- High-capacity operations requiring a large amount of involvement of air traffic controllers, and
- Urban missions in IMC where there is limited space to implement effective IMC procedures.

The majority of operations will need to be under VFR, although there will be routes that can be implemented that are available for operations in IMC.

During Horizon 1, the following options should be used to mitigate the impact of additional UAM traffic:

- Additional procedures, and
- Additional ATC staff.

These solutions are likely to act as stop-gaps until Horizon 2 is reached, as they do not provide long-term solutions to the growth of UAM.

HORIZONS 2 AND 3

Dedicated UAM corridors and routes and reserved airspace could be introduced to allow segregation of UAM traffic from RPT aircraft and other airspace users. As CNS technologies improve, airspace design standards and procedures will harness these improvements, resulting in less segregation and less restrictive separation requirements for all airspace users. New procedures and/or services could be implemented to minimise voice-based communication between the controller and the UAM vehicle pilot.

To ensure greater certainty for the completion of trips in adverse weather, procedure design standards will need to be developed specifically for UAM operations to enable IMC approach procedures.

In Horizon 3, highly dynamic airspace structures, or fewer airspace structures, will be used where safety and other performance outcomes can be achieved through the application of technology and procedures.

B.2 INFORMATION EXCHANGE SERVICE

B.2.1 SERVICE OBJECTIVE

The objective of the Information Exchange Service is to ensure shared situation awareness for all stakeholders by exchanging timely and accurate data from the ANSP and industry systems. As a result, the Information Exchange Service will enable the UATM Services to support safe and efficient operations.

B.2.2 GENERAL DESCRIPTION

Information Exchange must be aligned with ATM information management principles so far as is practicable. Information Exchange will provide accredited, quality-assured and timely information that will be used to support UAM and related operations. It will also monitor and control the quality of the shared information and provide information-sharing mechanisms that support UAM stakeholders.

The best possible integrated picture of the historical, real-time and planned or foreseen future state of the UAM environment will need to be assembled. This integrated picture will provide the basis for improved decision making by all UAM stakeholders.

Information Exchange will enable the wide availability of high-quality, relevant and consistent digital aeronautical data. The data will be presented to all airspace users in a usable format and will contribute to increased aviation safety and UAM operational performance. UAM stakeholders will depend on information management, shared on a system-wide basis, to make informed collaborative decisions for the best business and operational outcomes.

Within the UATM system, based on this operational concept, it will be the information that will be of significance rather than the technology that supports it.

Pertinent information will be available when and where required. UATM data has temporality, but to varying degrees in terms of frequency or magnitude, varying from almost static to very dynamic. Information will need to be tailored, filtered and accessed.

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21 As defined in the ICAO’s Global air traffic management operational concept.
The initial quality of the information provided will be the responsibility of the originator; subsequent handling must not compromise its quality. The Information Exchange Service will allow all participants to adjust information sharing to mitigate any proprietary concerns. Sensitivity with regard to some data will continue to be an issue and will be managed within the information management function.

Information Exchange will achieve a seamless transfer of relevant information between parties in a flexible, adaptable and scalable information environment. The Information Exchange Service will use globally harmonised digital data standards.

ATM-RELATED INFORMATION
The following broadly describes current ATM functionality that would form part of the inputs and outputs of Information Exchange. Applicable Information Exchange consists of, but is not limited to, the following:

- Aeronautical information (e.g. airspace structures, routes, airports/heliports)
- Flight information (e.g. aircraft type, departure and arrival ports, intent)
- Weather information (e.g. wind, temperature and pressure).

Aeronautical information can originate from a multitude of sources, such as surveys, aerodrome/aircraft operators and third-party airspace design organisations. Aeronautical Information Service (AIS) providers process data from originator sources and publish state AIPs. AIPs will consist of airport directories, charts, procedures and route supplements. Data coding houses obtain data from AIS providers and convert the data into formats usable by aircraft avionics manufacturers for uploading into aircraft flight management systems. Short notice information can be published via NOTAMs for activation of danger or restricted areas, low-level flying activities, crane operations or amendments to procedures.

Aircraft typically exchange information via radio or data links. The type of information exchanged will include ATC instructions, position reports and weather forecast updates.

UAM-SPECIFIC INFORMATION
A range of aeronautical information will be needed including the following:

- Airspace availability,
- Route structure,
- Frequencies,
- Vertiport departure and arrival procedures,
- UAM vehicle compliance with vertiport parameters such as size,
- Airspace definitions (e.g. volume),
- Non-standard operations,
- Vertiport FATO or stand availability (predictive),
- Vertiport service functions/facility availability (e.g. battery charging),
- Vertiport prioritisation landing rules,
- Vertiport operating modes, and
- Terrain/obstacle maps.

For pilots, vehicle operators, vertiport operators and the ANSP, real-time information will be the basis of decision making and will include the following:

- UAM vehicle status (e.g. position, intent, predicted timing of future status, onboard manifest), including any emergency status;
- Local weather information at departure, along the route and on arrival at the vertiport (both actual and forecast); and
- Flight planning information.

Strategically, UAM stakeholders will need a range of information, which will include but not be limited to the following:

- Projected/predicted demand,
- System available capacity,
- UATM system performance (e.g. efficiency),
- Predicted demand models,
- Operator/aircraft compliance,
- Airworthiness directives - fitness to fly,
- System integrity,
- Environmental compliance obligations, and
- Community-sought information (e.g. noise profile/performance).
B.2.3 CHALLENGES WITH CURRENT OPERATIONAL CAPABILITY

The following challenges to implementing the Information Exchange Service with current operational capability have been identified:

- Current ATM information-management practices are not optimised for dense UAM environments considering projected traffic density, high operational tempo, frequency of position adjustments and more granular operations.
- Current ATM CNS technologies have insufficient coverage and capacity for high-density UAM operations.
- ADS-B frequency saturation will become an issue as more aircraft are entering operations that will be transmitting on this frequency.
- Certain types of information that are pertinent to UAM operations but not relevant to other aircraft operations are not supported by current ATM information management systems.

B.2.4 PERFORMANCE EXPECTATIONS/BENEFITS (IN ICAO KPA TERMS)

An effective Information Exchange Service enables UAM operations to achieve benefits in the following areas:

- Timely and accurate information is the basis of all performance management. Effective Information Exchange enables UAM operations to achieve benefits across all performance areas.
- Importantly, information security assurance will be fundamentally based upon the approach used for Information Exchange.

B.2.5 UATM SERVICE MATURITY PHASES

HORIZON 1

Some Information Exchange could be provided at a vertiport through services similar to an AFIS with other automated services (Digital Automatic Terminal Information Service [D-ATIS], Digital Meteorological Service [D-MET] and Digital NOTAM [D-NOTAM]. Initial UAM vehicles will be piloted, incorporating voice communications as part of the Information Exchange.

Provision of a vertiport FATO reservation method will be necessary for Horizon 1. A slot system and/or a vertiport availability information management system will be needed for each vertiport.

HORIZONS 2 AND 3

The exchange of information with all key stakeholders, including vertiport operators, fleet operators, the booking platform, vehicle operators, the ANSP and USSs will commence. Reliance on voice-based communication is expected to decrease in Horizon 2.

As a foundational service, a mature Information Exchange system will be needed to support the density and frequency of operations expected in Horizon 2. The Information Exchange system will need to be sufficiently integrated to enable the exchange of information with applicable ATM and UTM information management systems.

As technologies mature, an ecosystem of sensors on the ground, on vehicles and on satellites will improve situation awareness for all stakeholders.

By Horizon 3, reduced reliance on current ATM technologies, including voice-based communication, will enable the introduction of autonomous UAM vehicles.
B.3 FLIGHT PLANNING AND AUTHORISATION SERVICE

B.3.1 SERVICE OBJECTIVE
The objective of the Flight Planning and Authorisation Service is to develop and maintain a plan and issue an authorisation in response to a flight request for a UAM vehicle movement. The flight plan and authorisation must align with the strategic objectives of the overarching UATM system (e.g. flow management constraints).

B.3.2 GENERAL DESCRIPTION
A flight authorisation includes the clearance for a UAM flight, the flight plan and a reservation for vertiport use. Where the provision of UATM Services is mandated, each UAM flight will require a flight authorisation. Flight planning requires a centralised element to ensure that all UAM operations take into consideration vertiport and airspace capacity and availability. A key component of flight planning is ensuring equitable access for all airspace users.

![Figure 12: Flight Planning and Authorisation Flow of Information](image)

Fleet operators and/or pilots will submit a flight request to the UATM system for a flight authorisation. A flight request will be made in advance or on demand at or near the time of departure (Figure 12). The flight request will include:

- departure vertiport;
- destination vertiport(s);
- time of departure;
- aircraft details (e.g. registration, navigation capabilities); and
- any preferred corridors, routes or areas of operation.

The Flight Planning and Authorisation Service will provide fleet operators and pilots with:

- a departure time window,
- a time window for any stops on the trip,
- an arrival time window, and
- a reserved FATO at the departure and arrival vertiport.

Flight planning can also include:

- a flight path, including specific corridors/routes; and
- a 4D trajectory, such as a metering time window at a point along the assigned flight path.
These elements of Flight Planning and Authorisation (vertiport FATO time window, flight path, 4D trajectory) define the parameters of an authorisation to fly. A window of time for arrival at a vertiport FATO will enable the pre-tactical deconfliction of arrivals and departures at vertiports.

Strategic deconfliction is delivered through airspace structures and procedures, while pre-tactical deconfliction is delivered through trajectory management. Responsibility for tactical deconfliction remains with the UAM vehicle pilot through see- or detect-and-avoid capabilities. However, the Conformance Monitoring Service described later will also contribute to tactical deconfliction.

A mature Flight Planning and Authorisation Service will include the use of 4D trajectories (Figure 13). 4D trajectories will provide a basis for pre-tactically deconflicting UAM vehicles across the whole flight. 4D trajectories will take into account the UAM vehicle performance characteristics. Flight planning will need to consider energy usage and vehicle endurance as part of the plan. It will also need to consider weather conditions and their potential effect on energy usage and vehicle endurance.

Before acceptance of a flight plan, the UAM vehicle’s capability, performance and state (e.g. predicted energy level at the start of the flight) must be compared with the plan to ensure it can be achieved. As the time of the planned flight approaches, the UAM vehicle state will need to continue to be compared with the plan to ensure that the flight plan can be met. The level of confidence that the UAM vehicle will depart on time will inform the real-time picture and the Flow Management Service as required.

Integration with the process and the flow of ground activities will help to predict the time required to comply with a flight plan. The nature of the mission (e.g. drop off, pick up, recharge) will change the duration that a UAM vehicle will need to be on the ground during or at the end of a mission or a flight leg.

**FLIGHT PATH PLANNING**

Where UAM routes or corridors are defined, the fleet operator can be assured that airspace access can be achieved through the Flight Planning and Authorisation Service. Flight Planning and Authorisation can be used to ensure that obligations related to noise management (e.g. time of day, route usage) and avoidance of sensitive airspace (e.g. for security or emergency reasons) is managed.

Flight planning will include options for use of different vertiports that allow the operator to determine different end-to-end journey-management options. The fleet operator and/or the UAM vehicle pilot will be responsible for accepting or rejecting the proposed flight plan.

In situations where UASs intend to use the same routes, the provision of critical data for flight planning will need to be the same. The Flight Planning and Authorisation Service must take into account all low-level airspace users that will be present in the same airspace to provide an integrated UAM vehicle flight plan.
VERTIPORT FATO RESERVATION

Vertiport FATO availability will significantly impact the capacity within the UATM system. Flight Planning and Authorisation will include a reservation for both the departing vertiport FATO and the arriving vertiport FATO, and if applicable, a stand.

Vertiport FATO reservation will need to extend to the transition zone to ensure separation of eVTOLs during transition. If multiple vertiports or vertiport FATOs are within the transition zone, the reservation of the transition zone needs to take this into account.

Reservations will minimise the amount of potential holding time for UAM vehicles at the arriving vertiport FATO. Reservation times will need to take account of any potential variability in the flight time, being wide enough to take into account likely airborne and ground-based variability, but also sufficiently narrow to ensure the efficiency of the system.

A trip can include prepositioning a UAM vehicle at the departing vertiport and moving the UAM vehicle to another vertiport after the flight. Therefore, an authorisation may include reservations for more than two vertiport FATOs.

Authorisations to use certain vertiport FATOs or to fly on certain corridors/routes will vary depending on the performance characteristics and capabilities of the UAM vehicle. These performance characteristics and capabilities will include manoeuvrability, CNS equipment, noise emissions and type of cargo.

CHANGES TO PLAN AND AUTHORISATION

A flight plan (and its associated authorisation) may need to be revised before or after departure due to the operator’s requirements or other requirements in the UATM or ATM system. Flight plan revision will need to include consideration of different options where possible. Flight plan revision will also need to consider the capability of the assigned UAM vehicle to undertake the changed plan. The fleet operator and/or the UAM vehicle pilot will be responsible for accepting the revised flight plan.

ALTERNATES

A flight plan will also include identification of alternate landing locations along the flight path to manage in-flight and vertiport emergencies, which would mean that the UAM vehicle cannot land at the destination vertiport. All stages of flight will require an alternate vertiport FATO or a suitable forced landing area to be within a specified distance. Flight paths will need to be planned giving consideration to the distance from available alternate landing locations.

The endurance of the vehicle and the general performance of the airframe will inform the required alternates at varying distances from the planned flight path.

B.3.3 CHALLENGES WITH CURRENT OPERATIONAL CAPABILITY

The following challenges to implementing the service with current operational capability have been identified:

- Due to the low density of helicopter operations in low-level airspace, current helipad booking systems are simple.
- Current allocations of uncontrolled airspace are based on the relatively low-density nature of air traffic within those airspace volumes.
- Helipad availability is not integrated with the current ATM system, so limiting any ability to coordinate traffic with helipad bookings.
- Current authorisation procedures cannot guarantee access to controlled airspace prior to departure.

B.3.4 PERFORMANCE EXPECTATIONS/BENEFITS (IN ICAO KPA TERMS)

An effective Flight Planning and Authorisation Service enables UAM operations to achieve benefits in the following areas:

- Safety - Pre-tactical deconfliction of UAM vehicle movements near vertiports and along routes/corridors.
- Environment - Adherence to environmental or noise obligations regarding vertiport and route/corridor usage.
- Capacity - Planned use of vertiport FATO resources ensuring the greatest use of the limited resources to maximise capacity.
- Flight efficiency - Timed use of vertiport FATO resources and use of routes/corridors minimising the airborne holding of UAM vehicles.
- Flexibility - The ability to plan in advance, request on demand and make changes to flight requirements.
- Predictability - Assurance of vertiport FATO accessibility for departure and arrival and route/corridor availability.
- Access and equity - Assurance that all airspace users can gain access to the low-level environment.
B.3.5 UATM SERVICE MATURITY PHASES

Initial implementation of the Flight Planning and Authorisation Service will focus on vertiport FATO availability as initial route/corridor structures will not yet be available and the initial number of vehicles will be low. As dedicated UAM airspace structures are established, route/corridor planning would be included within the service. To increase efficiency and capacity, 4D trajectories will be implemented. It is expected that the service would reach full maturity during Horizon 2.

HORIZON 1

During Horizon 1, current airspace structures would be used (e.g. helicopter routes). Access to controlled airspace would be through an ATC clearance, as with current aviation operations. Clearance would be provided by voice communications on arrival at controlled airspace. Information for ATC would include:
- aircraft type,
- destination,
- requested route, and
- requested level.

No guarantees of access could be provided earlier than this.

HORIZONS 2 AND 3

During Horizon 2, segregated UAM airspace could remove the need for clearance by ATC to access controlled airspace. ATC clearance will still be required in certain circumstances, including during off-nominal scenarios. Segregated UAM airspace would be used by many UAM vehicles. No tactical separation service would be provided by ATC in segregated UAM airspace.

A 4D trajectory (volume of airspace and time within that volume) would:
- allow strategic separation of UAM vehicles within segregated airspace;
- allow variability in the departure time, speed control and arrival vertiport FATO availability;
- allow separation to be maintained from other airspace users outside of the airspace structure (e.g. route/corridor) being used; and
- give the UAM vehicle operator assured information for the prediction of energy usage.

4D trajectories can cover the entire flight or just part of the flight. If a 4D trajectory is not required for the entire flight (e.g. free-route airspace), estimates for those sections would be required to determine time in other parts of the flight and arrival time.

During Horizon 3, data from autonomous aircraft and potentially other sources will supplement the Information Exchange Service and, in turn, will enhance flight planning approaches.

B.4 FLOW MANAGEMENT SERVICE

B.4.1 SERVICE OBJECTIVE

The objective of the Flow Management Service is to ensure that demand for UAM operations is met to the greatest extent practicable in the context of the limited resources in the airspace and vertiports.

B.4.2 GENERAL DESCRIPTION

To maximise the capacity of vertiport FATOs, Flow Management will be required to manage arrival and departure times/slots. Flight planning will be informed by the capacity available at each vertiport. If capacity changes at a vertiport, previously planned flights must be reviewed to ensure vertiport capacity is not exceeded.

Flow Management will be used to inform updates to flight plans based on changes to airspace or vertiport capacity. These updates will include inputs from Dynamic Airspace Management and/or Conformance Monitoring (e.g. adherence to feeder fix times).

To ensure UAM vehicle flight efficiency, it will be preferable to hold UAM vehicles on the ground (ground delay) rather than issue an airborne delay. Certain situations will lead to a reduction in capacity or zero capacity (i.e. no availability).

Flight plan changes due to Flow Management will need to consider the use of alternate vertiports in collaboration with UAM vehicle operators.

Some airspace users will require priority over other flights within a Flow Management system (e.g. emergency services).

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**STRATEGIC, PRE-TACTICAL AND TACTICAL FLOW MANAGEMENT**

Flow Management will be conducted in strategic, pre-tactical and tactical timeframes.

**Strategic Flow Management** - The purpose of the strategic planning phase is to account and plan for variables that can be foreseen within a long-term time frame. This will improve predictability and maximise the flexibility and efficiency of UAM operations in normal conditions. The strategic planning phase can commence at any time in advance of a particular airspace activity, from months up to 1 to 2 days before a flight. In strategic planning, vertiport capacity will be based on its configuration. While full schedule information will not be known due to the on-demand nature of operations, certain data can be used for pre-planning. This will include the following:

- Historic demand from scheduled and non-scheduled flights,
- Airspace availability or constraints,
- ATM and UATM resource availability (capabilities and capacity estimations), and
- Analysis of how the following operational changes can affect flow management:
  - New procedures,
  - New standards,
  - Availability of ATM and UATM Services,
  - Vertiport and airport facilities,
  - Seasonal weather conditions, and
  - Estimations of likely business and other non-forecast airspace user demands.

This data can be used to aid airspace organisation and management processes integrated as part of the overall airspace (ATM and UATM) network plan. Airspace organisation and management can be engaged as a strategic demand- and capacity-balancing tool by adjusting capacity. Procedures will be established to best suit the traffic flows and to assist traffic separation by the creation of discrete trajectories that can be reconfigured in line with the different demands on airspace at different times of the day and night. The dynamic nature of this is discussed in more detail as part of the Dynamic Airspace Management Service.

The goal of the strategic planning phase is to account and plan for variables that can be foreseen within the strategic time frame. The main benefit of strategic planning is the ability to be strategic or proactive rather than tactical or reactive in managing traffic flows.

**Pre-tactical Flow Management** - During the pre-tactical phase, flight plans, airspace availability and vertiport availability will be received, analysed and incorporated. Pre-tactical flow management would commence 1 to 2 days before the point of departure. It will need to be balanced as a part of a wider airspace plan (network management plan), as outcomes will impact not just UAM operations but all airspace users.

Flow Management plans developed in the strategic phase will be progressively refined, taking into account user preferences for flexibility, punctuality or service quality requirements—variables that typically cannot be foreseen in the strategic time frame. These plans will provide a framework that will give a reliable forecast of traffic demand and UAM and vertiport capabilities. They will be used to resolve demand and capacity issues among stakeholders.

At the same time, these plans will also estimate the reserve capacity and airspace needed for airspace users that, due to the tactical nature of their operations, cannot be planned with certainty in advance.

Plans developed in the pre-tactical planning phase will set out rules and parameters that will broadly outline the availability of airspace, routes, corridors, airports and vertiports. These plans will also provide estimates of the reserve capacity that will be needed for each day’s traffic. In the UAM environment, the plans will be published and further developed into network specific, time-defined plans that are finalised and promulgated at an agreed time before operation. Simulation and modelling will assist in determining an expected range where the UAM pre-tactical phase commences (expected to be much shorter compared to traditional ATM).

**Tactical Flow Management** - Tactical Flow Management commences at the point of departure and includes the time that the flight plan is being enacted. The tactical planning phase will continuously assess the flight plan against any potential resource, capacity or congestion problems. Real-time information, such as weather forecasts, traffic demand and airspace/vertiport availability, will be used on a continuous basis to predict flight plan impacts for both UAM vehicles in flight and those still pre-flight. This will occur in combination with the Dynamic Airspace Management Service and the Conformance Monitoring Service described later.
Updates to forecasts of local capacity bottlenecks throughout the UAM network will lead to an assessment of the impact of individual flight plans. The tactical situation will continuously inform whether and how the plan needs to be refined, both tactically and pre-tactically.

**MANAGING DEMAND VS CAPACITY**

The overall capacity for a UAM environment based on Flow Management principles will need to be understood strategically. The network-wide impact of tactical availability issues will need to be understood and planned for strategically. Patterns and events that could impact (increase) demand will be reviewed and planned for strategically to aid understanding and allow preparation for their impact. Vertiport capacity will initially be the greatest limitation to the Flow Management Service. However, in dense operations, airspace and/or route/corridor capacity will also become a limiting factor. To maximise airspace capacity, Flow Management will use 4D trajectories, which will consider vertiport departure and arrival times and be assessed as part of airspace authorisation decisions. Airspace and/or route/corridor capacity is expected to be impacted by the following:

- Weather,
- UAM vehicle separation standards,
- Procedures for transiting through controlled airspace,
- Emergency scenarios,
- UAM vehicles operating non-compliance,
- Noise management, and
- Airspace intrusion by a non-compliant vehicle.

The maximum capacity of a vertiport will need to be planned strategically and used as a basis for flight planning, with consideration of future potential capacity impacts. Vertiports can be used by a single operator or many operators. Some vertiports or urban environments will use scheduled movements where certain flight plans are standardised over time. There will be a mix of scheduled and unscheduled movements.

The maximum capacity of a vertiport will be defined by

- the number of FATOs;
- the number of stands;
- the amount of time required by a UAM vehicle on the vertiport FATO or stand for
  - loading and off-loading,
  - vehicle charging,
  - vehicle cleaning and maintenance,
  - pre-flight checks, and
  - taxi time;
- the amount of time required for arriving and departing UAM vehicles in the vertiport transition zone; and
- noise management restrictions (e.g. time of day, vehicle frequency).

The vertiport availability philosophy (e.g. slots and priority) will be defined between the vertiport operator and the ANSP or other applicable airspace managers. The operational capacity of a vertiport will be impacted by

- weather,
- vertiport FATO unavailability (e.g. due to scheduled maintenance or UAM vehicle failure on the FATO), and
- UAM vehicle flight plan non-compliance (e.g. due to passenger delays).

There may be a hub-and-spoke arrangement in the low-level airspace environment where hub vertiports have greater capacity and movements and spoke vertiports have less capacity and fewer movements. A point-to-point approach may, however, be used in certain locations where capacity requirements are spread more evenly.

Where vertiport capacity impacts can be determined pre-tactically (e.g. weather, some vertiport availability scenarios), this will be used as a basis for flight planning. Some predictions of capacity impacts will be inaccurate or subject to change (e.g. weather forecasts). Where unplanned vertiport capacity impacts occur, tactical changes to capacity will need to be made and updates to flight plans made tactically. Updates to flight plans made tactically will be communicated to the UAM vehicle/pilot through the Flight Planning and Authorisation Service.

Minor vertiport availability issues (e.g. slightly late departure of a UAM vehicle) will need to be handled tactically by small flight-plan adjustments for other UAM vehicles.
B.4.3 CHALLENGES WITH CURRENT OPERATIONAL CAPABILITY

The following challenges to implementing the Flow Management Service with current operational capability have been identified:

- Currently, in many urban environments, there is an insufficient number of heliports to sustain a viable UAM operation.
- Conventional ATM flow management systems do not monitor helipad operations and capacity.
- Conventional ATM flow management systems are used for pre-tactical purposes and lack the tactical capabilities required for high-volume UAM operations.
- Current tactical flow management relies on controller-pilot interaction.

B.4.4 PERFORMANCE EXPECTATIONS/BENEFITS (IN ICAO KPA TERMS)

An effective Flow Management Service enables UAM operations to achieve benefits in the following areas:

- **Safety** - Pre-tactically deconflicts traffic arriving and departing vertiports and reduces the amount of time in the air through ground-based holding.
- **Environment** - Reduces airborne holding and decreases flight noise as there will be less of a requirement to hold on approach to a vertiport. Flow Management also minimises the amount of energy that needs to be consumed.
- **Capacity** - Ensures that the greatest capacity is achieved from the available vertiport infrastructure and airspace structure.
- **Flight efficiency** - Minimises the required time to be airborne, thus ensuring that flight efficiency is not impacted by other UAM vehicle movements.
- **Flexibility** - Enables flight plans to be updated as required due to changes in the operational environment.
- **Predictability** - Ensures that a flight plan can be reliably implemented without impact from other UAM vehicle movements.
- **Access and equity** - Ensures that pilots and fleet operators can gain access in a transparent manner to the shared resources of vertiports and airspace.

B.4.5 UATM SERVICE MATURITY PHASES

**HORIZON 1**

The Horizon 1 Flow Management Service will focus on allocating and adjusting time slots at vertiports for UAM vehicles. A slot system and vertiport availability information management system will need to be developed for each vertiport.

**HORIZONS 2 AND 3**

During Horizon 2, as dedicated UAM airspace structures are developed, the Flow Management Service will begin providing pre-tactical Flow Management based on flight requests, capacity constraints and resource availability. Once Conformance Monitoring Services and/or Dynamic Airspace Management Services are available, tactical traffic flow management will be provided.

During Horizon 2, the Flow Management Service can involve UAM vehicles travelling in ATM-controlled airspace. Flow management will initially focus on segregated UAM operations, with ATM integration implemented at a later stage (i.e. a UAM metering fix time issued before crossing a final approach path to a runway).

By the end of Horizon 2, or in Horizon 3, Flow Management for ATM and low-level airspace should be integrated to maximise airspace efficiency.
B.5 DYNAMIC AIRSPACE MANAGEMENT SERVICE

B.5.1 SERVICE OBJECTIVE
The objective of the Dynamic Airspace Management Service is to maximise the performance of low-level airspace and its structures as environmental and operational needs shift. The service also aims to be responsive to ATM needs during nominal and off-nominal scenarios.

B.5.2 GENERAL DESCRIPTION
Airspace and route/corridor availability for UAM operations will vary for a number of reasons including the following:

- ATM requirements for airspace use (e.g. weather, TRA/TFR);
- UAS requirements for airspace use;
- Emergency or special circumstance requirements for airspace restriction, including
  - non-cooperative airspace users,
  - emergency aircraft operations,
  - ground-based threats, and
  - communications or surveillance outages/coverage issues;
- Environmental and weather conditions;
- Noise management restrictions (e.g. respite);
- Capacity needs; and
- Contingency management.
Airspace and route/corridor availability will be variously predictable and unpredictable. UAM airspace structures will need to have availability specified for time periods. Decisions about Flight Planning and Authorisation as well as Flow Management decisions will need to be based on known airspace and route/corridor availability. Following changes in airspace and/or route/corridor availability, existing authorisations, including for those already in flight, must be reviewed to determine how the changes affect the flight plans and whether the existing flight authorisations need to be cancelled or amended.

Predicted airspace-impacting scenarios will need to be planned for strategically through the use of predefined procedures. The network-wide impact of airspace availability issues will need to be understood and planned for strategically. The use of dynamic routes/corridors can

- provide strategic segregation of aircraft, thus increasing available capacity;
- share aircraft noise to prevent concentration over one community; and
- ensure business continuity for fleet operators and vertiports.

Dynamic routes/corridors will require a set of predefined airspace structures and associated procedures, or a means for safely generating routes/corridors tactically within predefined airspace. When airspace structures are made available or unavailable, procedures will be needed to ensure that safety is appropriately managed through the change.

### B.5.3 CHALLENGES WITH CURRENT OPERATIONAL CAPABILITY

The following challenges to implementing the Dynamic Airspace Management Service with current operational capability have been identified:

- Current ATM capability is restricted to procedures for enabling or disabling routes/corridors and airspace use for helicopter traffic (e.g. LOAs for clearances to operate in certain areas).
- ATM does not currently have the capability to define dynamic airspace structures for UAM vehicles in the low-level airspace.

### B.5.4 PERFORMANCE EXPECTATIONS/BENEFITS (IN ICAO KPA TERMS)

An effective Dynamic Airspace Management Service enables UAM operations to achieve benefits in the following areas:

- **Safety** - Minimises airspace safety risk by controlling airspace access.
- **Environment** - Provides a mechanism for noise sharing through the use of alternative routes/corridors.
- **Capacity** - Enables additional routes/corridors and airspace to be made available to increase capacity.
- **Flight efficiency** - Ensures that the most efficient routes/corridors can be made available where possible, even if not in an ongoing manner.
- **Flexibility** - Allows airspace to be used periodically that otherwise would have to remain reserved if it could not be made available dynamically.
- **Predictability** - Provides a system for identifying what airspace is available at what time. Supports business continuity for vertiports, fleet operators and their customers despite airspace changes.
- **Access and equity** - Ensures the greatest possible availability of airspace whilst enabling prioritisation of airspace access.

### B.5.5 UAM SERVICE MATURITY PHASES

**HORIZON 1**

Dynamic Airspace Management will be limited to current tactical ATM procedures as well as largely static airspace volumes. This will be adhered to by UAM operations and managed through the Information Exchange Service by way of existing formats (e.g. AIP and NOTAMS). Dynamic elements of traffic management in Horizon 1 will focus on the availability of procedures for use by pilots as assigned by ATC.

**HORIZONS 2 AND 3**

Dynamic Airspace Management will be more holistically implemented in Horizon 2. Initially, Dynamic Airspace Management will predominantly focus on the use of pre-defined airspace structures but may include some previously undefined structures (such as TFR/TRA polygons). Advances in automation are expected to enable Dynamic Airspace Management to develop new airspace structures in real time, or near-real time, to minimise disruption to or deviation from existing flight plans. This will likely be implemented in a mature Horizon 2 or Horizon 3.
B.6 CONFORMANCE MONITORING SERVICE

B.6.1 SERVICE OBJECTIVE
The objective of the Conformance Monitoring Service is to identify non-conforming vehicles that impact low-level airspace operations and to ensure timely triggers and mitigation responses for impacted UAM vehicles. This data will also support the systemic review and analysis of UAM operational performance.

B.6.2 GENERAL DESCRIPTION
The Conformance Monitoring Service ensures that all UAM vehicles in the low-level airspace are in compliance with the flight plan contained in the flight authorisation. In addition to monitoring flight compliance within a route/corridor, the service will also identify UAM vehicles that are not in compliance with a 4D trajectory. Accountability for compliance will lie with pilots and UAM vehicle operators. The Conformance Monitoring Service serves as an additional means of ensuring safety and mitigating risks to UAM operations. Communication with a vehicle will be initiated when non-compliance is predicted and/or detected.

A vehicle’s non-compliance with a 4D trajectory may have a negative impact on the safety and efficiency of the UATM system. At times, UAM vehicles will not be able to comply due to situations outside of their control, such as the following:

- Weather,
- UAM vehicle system or system component degradation or failure (e.g. vehicle or pilot performance),
- UATM system or system component degradation or failure (e.g. degradation of navigation information),
- Onboard issues or emergencies, and
- Requirements to deviate for operational reasons (e.g. ATC requirements).
Higher levels of assurance of operational compliance can be achieved through the Conformance Monitoring Service. Data from this service supports both tactical decisions and systemic performance analysis.

**TACTICAL CONFORMANCE MONITORING**

Tactical Conformance Monitoring allows the traffic management authority to identify and mitigate non-conformance by low-level airspace users in a real-time environment. The Conformance Monitoring Service will also identify an emergency on a UAM vehicle that requires the involvement of emergency services. It could also be used to tactically monitor the presence of non-cooperative objects operating within low-level airspace.

Conformance Monitoring will occur through information received via multiple sources including:

- navigation and surveillance information from UAM vehicles\(^\text{23}\),
- reporting by the UAM operator or pilot of emergency or inability to comply,
- non-cooperative vehicle surveillance, and
- other surveillance sources.

Mitigation responses will include:

- issuing alerts to non-compliant operators and other low-level airspace users,
- providing alternative flight plans for impacted UAM vehicles during emergency scenarios,
- requiring other airspace users to adjust their flight plans (which can occur seamlessly in a similar manner to Dynamic Airspace Management Changes and Flow Management Changes or require more active management), and
- reporting of emergencies to emergency services.

Some non-conformance events will be rectifiable through return to an authorised flight plan or the issue of a new flight plan. However, other non-conformance events may end up in a contingency state wherein the UAM vehicle cannot return to a conforming operation, thus necessitating further action.

**SYSTEMIC PERFORMANCE ANALYSIS**

Information from the Conformance Monitoring Service will inform thresholds for airworthiness, ATC procedures, airspace and procedures design, as well as community perception. In terms of performance analysis, the Conformance Monitoring Service will collect information about non-compliance.

This information will be provided to relevant stakeholders for occurrence management as well as wider safety performance monitoring and systemic analysis. Stakeholders who will benefit from performance analysis from Conformance Monitoring include the following:

- ANSPs,
- Airspace regulators / NAA,
- UAM vehicle pilots,
- UAM vehicle fleet operators,
- UAM vehicle manufacturers and equipment installers,
- USSs, and
- Accident investigation authorities.

Comparison of safety performance monitoring reports from the Conformance Monitoring Service and UAM vehicle operators will provide useful insights into the maturity of safety management practices of participants in the UAM environment.

Hotspot analysis of low-level airspace will allow stakeholders to understand key risks in the low-level airspace environment.

**B.6.3 CHALLENGES WITH CURRENT OPERATIONAL CAPABILITY**

Implementing the Conformance Monitoring Service with current operational capability presents the following challenges:

- There is frequently incomplete existing surveillance across low-level airspace.
- Current lateral and vertical units of measurement for aviation may not be of sufficient resolution for UAM Conformance Monitoring.
- The current ATM system is incapable of monitoring the conformance of the expected number of low-level airspace users.
- ADS-B has limited scalability due to design factors and potential issues regarding the quantity of ADS-B reports overwhelming existing ATM systems.
B.6.4 PERFORMANCE EXPECTATIONS/BENEFITS (IN ICAO KPA TERMS)

An effective Conformance Monitoring Service enables UAM operations to achieve benefits in the following areas:

- **Safety** - Real-time and systemic awareness of operations that could impact the safety of the low-level environment.
- **Efficiency** - Known historical use of airspace provides information to assist in improving future use.

B.6.5 UATM SERVICE MATURITY PHASES

**HORIZON 1**

During Horizon 1, conformance monitoring will rely on currently available ATM CNS capability as well as ATM and regulatory reporting mechanisms. In Horizon 1, there will be an opportunity to increase surveillance and communications coverage through additional implementation of systems such as ADS-B and other communications infrastructure. ADS-B does not necessarily scale well with high traffic density, and coverage is possibly insufficient for all phases of flight.

Onboard UAM vehicle systems will be able to collect and disseminate additional information that can be used to inform conformance monitoring. However, a data collection system will need to be implemented.

It will be necessary to define where and/or under what scenarios Conformance Monitoring will be necessitated during the early phases of Horizon 1. Scenarios could include adherence to routes in accordance with noise abatement procedures. Conformance Monitoring capabilities established in Horizon 1 would provide evidence that would support the safety case and/or community acceptance for moving UAM operations to Horizon 2 (and similarly between Horizon 2 and 3).

**HORIZONS 2 AND 3**

In Horizon 2, Conformance Monitoring will provide an ongoing set of information to manage the operational safety risk of UAM operations. There will be an opportunity to increase surveillance and communications coverage for all stakeholders (including the pilot) through the implementation of current and new communications and surveillance infrastructure (e.g. new cooperative surveillance technology).

In Horizon 3, Conformance Monitoring will be important for resolving conflicts between manned and autonomous operations.
## ANNEX C

## CONOPS SIMULATION AND ANALYSIS

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C CONOPS SIMULATION AND ANALYSIS

C.1 KEY INDICATORS AND METRICS

Below is an initial list of indicators and metrics that will be essential for assessing the overall performance of the UAM environment as well as the effectiveness of technologies and procedures that are used to implement the services described in this CONOPS. Monitoring these indicators and metrics will be important after implementation to ensure UAM operations and the airspace remain optimised.

- Vertiport capacity
- Vertiport demand
- Vertiport utilisation
- Vertiport distribution
- Vertical and horizontal separation
- Airspace capacity
- Airspace demand
- Route/corridor capacity
- Route/corridor demand
- Flight route efficiency
- Flight route throughput
- Flight 4D compliance/non-compliance
- Safety occurrences near vertiports
- Safety occurrences in controlled airspace
- Safety occurrences outside controlled airspace
- Compliance with environmental obligations
- Airspace access authorisation approval rate

C.2 REAL-TIME HUMAN-IN-THE-LOOP ANALYSIS

C.2.1 BACKGROUND

Low-level air traffic between the Melbourne CBD and Melbourne Airport can create a challenging operational environment. Essendon Airport lies between the CBD and Melbourne Airport (Figure 14) and has a dynamic and often complex flow of traffic. Essendon tower also manages the low-level traffic between Melbourne Airport and the CBD. Flights operating between the CBD and Melbourne Airport require a clearance to enter Essendon airspace, and air traffic controllers at Melbourne and Essendon towers need to coordinate this traffic. As UAM operations increase along this route, controllers at Essendon Airport will need new procedures and technologies for managing this growing traffic volume.
C.2.2 METHOD

A high-fidelity simulation of Essendon tower traffic tested the degree to which the current ATC system could accommodate a growing number of UAM operations between the CBD and Melbourne Airport. The simulator provided a realistic out-the-window view of the Essendon traffic so that the controllers could scan, coordinate and manage traffic in a naturalistic manner (Figure 15).

Figure 15: The Airservices High-Fidelity Tower Simulator
EXPERIMENT DESIGN
The simulation manipulated the following three independent variables by using six conditions (Table 1). Each traffic scenario lasted for 45 minutes, and the controllers used current-day ATC procedures to manage traffic.

- Traffic complexity (medium and high) - Two traffic scenarios, one of medium and one of high complexity, were used. Although the scenarios were designed for training new Essendon tower controllers, the high-complexity scenario reflected traffic movements that are typically experienced in the tower. Baseline scenarios were used for comparing airspace capacity and human performance under different conditions. The same scenarios were used for conditions with UAM traffic both with and without an LOA.

- UAM traffic (with and without UAM operations) - UAM operations operated as VFR traffic. They were timed to depart at 5-minute intervals (both to and from the airport), to simulate when the UAM industry approaches Horizon 2. In these scenarios, the controllers were tasked with managing a high-tempo flow of two-way UAM operations and integrating these flights into typical traffic flows.

- Coordination (with and without an LOA) - An LOA procedure required Melbourne tower to call the Essendon Aerodrome Controller (ADC) when a UAM operation was about to depart for Essendon airspace. This variable was included to test whether an LOA would reduce coordination workload and improve situation awareness.

<table>
<thead>
<tr>
<th>Traffic Mix and Procedures</th>
<th>Traffic Complexity Level</th>
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<tbody>
<tr>
<td>Baseline (without UAM traffic)</td>
<td>Condition 1</td>
</tr>
<tr>
<td>With UAM Traffic (without LOA)</td>
<td>Condition 3</td>
</tr>
<tr>
<td>With UAM Traffic (with LOA)</td>
<td>Condition 5</td>
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</table>

PARTICIPANTS
Due to the global pandemic, the project had access to only two tower controllers. However, they were both highly experienced (with 6 and 15 years of experience, respectively) in managing Essendon traffic. For the simulation, one controller performed the role of the ADC while the other worked in the combined Surface Movement Controller (SMC)/Coord position. The combined SMC/Coord position is the norm at Essendon tower.

These positions have different roles and responsibilities. The ADC provides aerodrome control within airspace released to the tower and on the runways. The SMC controls ground vehicles and aircraft on the apron and taxiways, excluding the runways. The Coord coordinates with external parties and carries out flight data duties. In addition, training and operations work is undertaken concurrently with SMC endorsement.

METRICS
Qualitative and quantitative data were collected to compare airspace capacity and controller performance across six conditions. The quantitative metrics assessed the following:

- Controller workload - The National Aeronautics and Space Administration (NASA) Task Load Index (NASA-TLX)\(^{24}\) was used to collect controller workload ratings for each scenario. This technique collects subjective ratings and weights the ratings using six factors.

- Communication demands - Data about the number and duration of air-ground radio communications were collected for each scenario.

- Situation awareness - Subjective ratings of controllers’ situation awareness were collected using the Situation Awareness Rating Technique (SART)\(^{25}\). SART uses 10 dimensions to assess situation awareness.

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Qualitative data were collected through a series of debriefing interviews. The controllers shared their experiences in managing UAM flights and discussed possible solutions to the challenges they encountered.

C.2.3 RESULTS AND ANALYSIS
The number of data points was limited because only two controllers participated in the simulations. However, given that both controllers were highly experienced in managing traffic at Essendon, the results provide reliable insights into the feasibility of UAM operations and the limitations of the existing ATC system. The simulation identified the following major issues:

- **Challenges in prioritising traffic in the complex traffic mix** - Integrating the high-tempo flow of UAM traffic was challenging given the complex traffic mix and the need to prioritise IFR over VFR traffic.
- **Challenges in establishing effective standard traffic patterns** - Integrating the high-tempo flow of UAM traffic on a dynamic basis with other flights.
- **High mental workload** - Demands from managing traffic and maintaining situation awareness created high levels of workload.
- **Decrease in situation awareness** - Traffic management became very reactive with limited ability to predict and plan for incoming UAM operations.
- **Airspace saturation** - The procedures limited the amount of airspace that could accommodate UAM operations, and the airspace became saturated quickly, with only four UAM operations present.

CHALLENGES WITH PRIORITISING TRAFFIC IN THE COMPLEX TRAFFIC MIX
**Mix of VFR and IFR traffic** - Although there was a high-tempo flow of UAM operations, controllers still needed to prioritise IFR vehicles over VFR traffic. The prioritisation of IFR flights made it difficult to effectively integrate the VFR UAM operations with other traffic.

CHALLENGES WITH ESTABLISHING A STANDARD TRAFFIC PATTERN
Controllers first encountered UAM traffic under medium-complexity conditions in Condition 3. In this scenario, controller workload increased greatly as there was no initial plan for standardising the flow of UAM operations. In later scenarios, establishing a standard traffic pattern remained challenging because of the following:

- **The mix of light and medium category aircraft** - The mix of light- and medium-category aircraft made it difficult to integrate UAM operations into a standard traffic pattern.
- **The need to manage unexpected flights** - UAM operations were highly dynamic as they departed frequently and had to be integrated with other traffic. As a result, traffic management became very reactionary.
- **The presence of high priority medical emergencies** - Emergency aircraft (such as medical transport helicopters) needed to be prioritised over UAM operations. These situations increased traffic complexity.

HIGH MENTAL WORKLOAD
Operations with high-tempo UAM operations placed significant demands on the controllers. The mental workload demands were driven by the need to

- prioritise IFR over VFR aircraft,
- manage a complex mix of light- and medium-category aircraft,
- make sequencing decisions,
- establish the traffic pattern,
- make frequent radio calls,
- maintain situation awareness, and
- coordinate with Melbourne tower.

These tasks increased mental workload for both the ADC and SMC in the medium- and high-complexity scenarios. Subjective workload was rated on a scale of 1 (extremely low) to 100 (extremely high) across six factors. A weighted score was then calculated based on the ratings of the six factors (Figure 16).

The controllers did not believe that the high mental workload would be sustainable for a long duration. The frequent departure of UAM operations offered little opportunity for a lull in traffic demand. The sustained demand on mental workload would be likely to accelerate the risk of fatigue.

Effect of the LOA - The LOA—requiring Melbourne tower to call Essendon tower prior to the release of each UAM operation going to the CBD—lowered subjective workload ratings for both controller positions. The LOA seemed to benefit the SMC most during the high-complexity scenarios, but it was still higher than in the baseline scenarios. The results suggest that an LOA is beneficial and should be considered when planning implementation of Horizon 1.
**Communication demands** - The ADC made considerably more radio calls when UAM operations were present. Figure 17 shows the number of radio calls that the ADC made in each of the 45-minute scenarios. In the moderate- and high-complexity scenarios, the number of radio communications peaked when there was no LOA in place. However, even with the LOA, radio communications did not decline significantly.

In the baseline moderate-complexity scenario, the ADC made 75 calls, but with UAM operations and an LOA, the number grew by 37% to 103. Similarly, in the high-complexity baseline condition, the ADC made 95 calls, but with UAM operations and an LOA, the number grew by 30.5% to 124. The results strongly suggest that revised or new procedures are needed to minimise radio communications. Furthermore, the increase in communications highlights the pressure that Horizon 1 UAM operations may place on the demand for radio frequency. Such an impact would affect all piloted aircraft in the vicinity.
DECREASE IN SITUATION AWARENESS

Controllers rated their situation awareness using SART. They rated 10 factors that contribute to overall situation awareness on a scale of 1 (low) to 7 (high). They also provided feedback on how UAM operations affected their ability to achieve and maintain situation awareness (Figure 18 and Figure 19). High-tempo UAM operations led to the following potential human factors risks:

- **Decline in team resource management** - As workload increased, the ADC had a greater need for the SMC to assist in maintaining situation awareness. However, the SMC’s workload increased in tandem and they did not have the spare capacity to provide the required assistance. Similarly, the ADC also found it difficult to maintain a shared situation awareness with the SMC. Degradation of a shared situation awareness and a decline in team resource management highlight potential safety and human factors risks.

- **Reduced ability to plan for future events** - Due to the extremely high workload, both controllers became reactionary and found it hard to plan for future events. In short, the controllers found it difficult to predict and plan for the future situation.

- **Limited spare mental capacity** - An analysis of the situation awareness ratings found a notable decline in the ADC’s spare mental capacity during high-complexity scenarios. At baseline for the high-complexity condition, the ADC had a moderate degree of spare mental capacity (5 out of 7), but with frequent UAM operations, the spare capacity declined to 1 out of 7, reflecting high demands on mental workload. The lack of spare mental capacity creates safety risks that include accelerated fatigue and a degradation in the ability to handle unexpected events. The SMC had more spare mental capacity than the ADC in high-scenario conditions, which suggests that the LOA had a positive effect on SMC performance.

- **Excessive instability, complexity and variability in the situation** - Subjective ratings also reflected the controllers’ perceptions of traffic instability, complexity and variability (i.e. predictability). While the baseline scenarios were rated low to moderate for these three factors, scenarios with UAM operations were rated highly, indicating that these scenarios were difficult to manage and predict.

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**Figure 18: ADC Subjective Ratings of Contributory Factors to Situation Awareness**
With high-tempo UAM operations and the need to integrate these flights with the typical traffic at Essendon, the airspace quickly became saturated. The ADC managed a maximum of four airborne UAM operations while also managing the demands of other traffic. As more UAM operations requested a clearance over time, they experienced delays due to airspace saturation. The limitations were due to the following:

- The need to prioritise IFR over VFR traffic
- Demands from managing the dynamic flow of other aircraft in and out of Essendon Airport
- A limited volume of airspace, partly due to legislative requirements that require flights to remain not less than 1,000 ft above populated areas and flights over Essendon to fly a minimum altitude of 1,300 ft Above Mean Sea Level (AMSL), accounting for local terrain. Generally, the flights from the CBD to Melbourne Airport are given a standard flight level of 1,500 ft AMSL.

At the end of the high-complexity scenarios, there were at least five UAM vehicles still on the flight progress board waiting for clearance to enter Essendon airspace. If the traffic scenarios had continued, the delays would have escalated and more UAM operations would have been delayed. The results support the need for airspace structures and procedures to increase airspace capacity while minimising the demands on controllers.

C.2.4 PROPOSED SOLUTIONS FOR THE IMPLEMENTATION OF UATM

The following potential solutions may provide a scalable framework to mitigate the risks from high-tempo UAM operations in Horizon 1.

ESTABLISH A DEDICATED NETWORK OF UAM CORRIDORS

The establishment of dedicated corridors would enable UAM operations to move frequently and efficiently while minimising workload demands on ATC. The corridors could be based on the following procedures:

- ATC would not apply a separation standard in the corridor.
- ATC would not apply a separation standard between the corridor and other airspace users.
- Other airspace users (e.g. helicopters) would need to be able to maintain their own segregation from the corridor.
- Corridors would be established for the day of operations in the LOA with ATC.
- When airports change their runway mode, there may be the need to close one corridor and open a different corridor after the change in runway mode.
- Initial consideration of VFR operations and further consideration of IMC flights would be required.
require uam vehicles to be equipped with appropriate navigation and surveillance avionics

- High-precision UAM operations will improve safety and offer assurance to ATC that the vehicles are going to maintain a safe separation.
- UAM vehicles will need to be capable of self-separation inside the corridor.
- UAM vehicles must be able to self-monitor conformance with the flight plan in the corridor.
- UAM operations (and potentially other airspace operations in the vicinity) will need to have Area Navigation (RNAV), Required Navigation Performance Authorisation Required (RNP-AR) capability or better.
- UAM vehicles will need to be capable of precise positioning and give a level of assurance for ATC and all airspace users that eVTOLs will stay in the defined corridors.
- UAM vehicles will need the ability to monitor and communicate with each other. Communication does not need to be through voice.

enable uam vehicles to operate at a low altitude inside the corridor

Lower-altitude corridors will enable UAM vehicles to avoid conflicts with other flights in the low-level airspace, such as aircraft on approach or departure.

minimise community impacts

UAM operations should avoid flying over residential areas, schools and care facilities, such as hospitals, to minimise noise and visual disturbances. Instead, UAM operations should opt for routes over parkland and industrial areas, railroad tracks, existing highways, etc. while also seeking to fly as directly as possible. Where this is not possible, a new route or procedure may be needed to conform to eVTOL performance capabilities in order to fly as directly as possible.

ensure availability of emergency landing sites

UAM operations must always be assured that emergency landing sites are available throughout the flight route. These sites may include specifically reserved vertiport FATOs with predefined escape routes from the corridor.

eliminate voice communications for uam flights

As UATM matures, operations should seek to evolve toward communications without the need for voice. The high-tempo UAM operations would otherwise create a voice communication workload that is untenable in the long term.

reduce randomised traffic

Improvements in the predictability of traffic flow will reduce controller workload and enhance controllers’ ability to maintain situation awareness. If UAM operations have to fly in corridors, and other aircraft need to follow a rigid route to avoid the UAM corridor, ATC is less likely to have to manage traffic coming from random directions.

conclusion and next steps

This simulation examined the effect of UAM operations on controller performance in an urban environment where UAM operations need to interact with ATC. The rapid rate at which the airspace reached a saturation point and the onset of flight delays to UAM operations strongly suggests that the Horizon 2 phase of UAM operations will come quickly. As such, ANSPs should be encouraged to start planning for Horizon 2 operations prior to the introduction of eVTOLs so that changes to airspace procedures and technical systems are planned and tested strategically.

The existing ATC system will need to be augmented to address the issues highlighted in this initial simulation. New procedures for coordinating traffic and establishing traffic patterns will likely become necessary, particularly as the number of vertiports grows and the complexity of the UAM operational network evolves. These changes will help to ensure that the low-level airspace continues to operate safely, reliably and efficiently, but they will need to be developed in consultation with airspace regulators and vertiport operators as well as communities. Furthermore, these procedures will need to be developed with long-term airspace integration in mind.
THE KEY OBJECTIVES OF THE FAST-TIME SIMULATION WERE TO ESTABLISH THE LIMITATIONS OF THE CURRENT SYSTEM AND IDENTIFY THE BENEFITS OF INTRODUCING UATM SERVICES.
C.3 FAST-TIME SIMULATION

C.3.1 BACKGROUND
The key objectives of the fast-time simulation were to establish the limitations of the current system and identify the benefits of introducing UATM Services, including dedicated UAM corridors and Flow Management Services.

A busy four-hour period was simulated across three scenarios by using TAAM (Total Airspace and Airport Modeller). The simulation included historic Melbourne basin traffic and a UAM traffic schedule with operations transiting between three vertiports in a UAM network across the Melbourne area: Melbourne Airport, the Melbourne CBD, and Geelong.

Twelve UAM vehicles operated under VFR in the UAM network where the frequency of the operations varied between vertiport pairs. Each hour, there were approximately 7 return trips between the Melbourne Airport and the Melbourne CBD, 1.5 return trips between Melbourne Airport and Geelong and 1 return trip between Melbourne CBD and Geelong. The schedule was designed to simulate high-volume operations based on the number of stands available within the network.

C.3.2 METHODOLOGY
The simulation assessed three scenarios and provides results in terms of flight time, delay and conflict analysis. This section describes the modelling techniques, assumptions and data used in the evaluation of the scenarios. The outputs of each simulation are presented in the results section.

SIMULATION SCENARIOS
Table 2 describes each of the simulation scenarios.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
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<tbody>
<tr>
<td>Scenario One</td>
<td>The routes used by UAM vehicles between each of the three vertiports are defined using existing helicopter tracking. UAM operations were integrated alongside existing traffic.</td>
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<tr>
<td>Scenario Two</td>
<td>The tracking used by UAM vehicles between each of the three vertiports are contained within dedicated UAM corridors.</td>
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<tr>
<td>Scenario Three</td>
<td>This is the same as Scenario Two, with Flow Management Services in addition. Flow Management is implemented with 1 nautical mile (NM) longitudinal separation. The simulation held aircraft on the ground instead of applying airborne holding in order to preserve eVTOL battery life.</td>
</tr>
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The fast-time simulation included a level of fidelity for operations in the Melbourne basin to capture key conflicts that are likely with other aircraft operating from Essendon, Melbourne and Avalon Airports.

Runway configuration - Basic runway layouts and associated arrival and departure routes were modelled in the simulation for Essendon (Rwy26 arrivals, Rwy17 departures), Melbourne (Rwy16 arrivals, Rwy27 departures) and Avalon (Rwy18 arrivals/departures).

Vertiport configuration - A vertiport was modelled with 8 stands at Melbourne Airport. Vertiports at Melbourne CBD and Geelong were modelled with 3 stands each.
UAM TRAFFIC DEVELOPMENT

Twelve UAM vehicles were scheduled at regular intervals in the UAM network. Each vehicle operated on the same route. A turn-around time of 13 minutes was included between flights. Flights were planned to fly at 1000ft AMSL. Nominal route frequencies are shown in Table 3.

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<thead>
<tr>
<th>Route</th>
<th>Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melbourne Airport ↔ Melbourne CBD</td>
<td>7</td>
</tr>
<tr>
<td>Melbourne Airport ↔ Geelong</td>
<td>3</td>
</tr>
<tr>
<td>Melbourne CBD ↔ Geelong</td>
<td>2</td>
</tr>
</tbody>
</table>

NON-UAM TRAFFIC

Regular IFR and VFR traffic were sampled from the 23rd January, 2019 between 0900-1300 local for use in the simulation. This represented 43 movements per hour at Melbourne Airport and 13 movements per hour at Essendon Airport. These movement numbers correspond to the 80th percentile of movements for 2019 at both Melbourne and Essendon and combined the 90th percentile for movements frequency in 2019. This represents a high traffic volume at these airports.

PARAMETERS

An arrival separation of 1 NM was applied in each scenario between arriving UAM vehicles.

In lieu of an established separation standard for UAM operations, the following conflict parameters were used to identify conflicts between aircraft when the following distances were breached:

- Between two UAM vehicles: 0.25 NM (horizontal) and 1000ft (vertical)
- Between an UAM vehicle and non-UAM aircraft: 1 NM (horizontal) and 1000ft (vertical)

A 2NM box was used around Essendon Airport to identify when delay would be required for UAM vehicles transiting overhead.

DATA INPUTS

Estimated flight times that were used to build the UAM flight schedule in each scenario can be found in Table 4. In each scenario, twelve UAM vehicles flew back and forth between two locations. The estimated airborne flight times were used to calculate when the next flight using the same aircraft would depart (with an assumed thirteen-minute turnaround time).

<table>
<thead>
<tr>
<th>Route</th>
<th>Scenario One</th>
<th>Scenario Two</th>
<th>Scenario Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melbourne Airport ↔ Geelong</td>
<td>32</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>Melbourne Airport ↔ Melbourne CBD</td>
<td>12</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Geelong ↔ Melbourne Airport</td>
<td>32</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Melbourne CBD ↔ Melbourne Airport</td>
<td>12</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Geelong ↔ Melbourne CBD</td>
<td>28</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>Melbourne CBD ↔ Geelong</td>
<td>35</td>
<td>33</td>
<td>33</td>
</tr>
</tbody>
</table>
ASSUMPTIONS
Given the need for Essendon Airport to manage departing and arriving traffic as well as traffic transiting overhead between Melbourne Airport and the CBD, transiting VFR flights often experience a delay when requesting clearance to enter the Essendon airspace. Expected delays imposed on UAM operations in Scenario One were added to UAM flight times in the post processing of results. The following approximate delays were added based upon the experience of Essendon Tower subject matter experts:

- An indicative delay of 60 seconds was added to an UAM flight time where it transited within 2NM of Essendon at the same time an Essendon departure occurred.
- An indicative delay of 120 seconds was added to an UAM flight time where it transited within 2NM of Essendon at the same time an Essendon arrival occurred.

C.3.2 RESULTS
This section provides the comparative results from the three scenarios. Sections include UAM flight times, UAM delays and conflict analysis for each scenario.

UAM FLIGHT TIMES
Table 5 provides a comparison of average flight times between each of the scenarios. The average flight time across all UAM flights in each simulation is:

- Scenario One - 18.9 minutes (92 flights)
- Scenario Two - 18.8 minutes (84 flights)
- Scenario Three - 18.6 minutes (84 flights)

<table>
<thead>
<tr>
<th></th>
<th>Melbourne Airport ↔ Geelong</th>
<th>Melbourne Airport ↔ Melbourne CBD</th>
<th>Geelong ↔ Melbourne Airport</th>
<th>Melbourne CBD ↔ Melbourne Airport</th>
<th>Geelong ↔ Melbourne CBD</th>
<th>Melbourne CBD ↔ Geelong</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario One</td>
<td>35.7</td>
<td>10.3</td>
<td>30.2</td>
<td>12.5</td>
<td>27.4</td>
<td>32</td>
</tr>
<tr>
<td>Scenario Two</td>
<td>34.3</td>
<td>11.1</td>
<td>32</td>
<td>11.2</td>
<td>26.8</td>
<td>29.2</td>
</tr>
<tr>
<td>Scenario Three</td>
<td>34.3</td>
<td>11.1</td>
<td>31.9</td>
<td>10.9</td>
<td>26.2</td>
<td>29.2</td>
</tr>
</tbody>
</table>

Each of the scenarios contained approximately four hours of UAM operations. Due to the longer estimated flight times (and track distances) associated with Scenarios Two and Three, they each had 84 UAM flights. Scenario One had 92 UAM flights; the higher frequency of flights in this scenario contributed to additional delay incurred by flights relative to the other two scenarios.

In Scenario One, during the four hours for which Essendon Airport movements were loaded into the simulation, 25 UAM vehicles flew within a 2 NM box centred on the aerodrome reference point during the period of at least one movement at Essendon Airport. These UAM flights were all flying between Melbourne Airport and the CBD (twelve were heading north and thirteen heading south). Of these interactions with an Essendon movement, nine involved a departure and sixteen involved an arrival. This resulted in 41 minutes of additional flight time (airborne holding) being added to the Scenario.

Table 6 shows the delays incurred by the UAM operations in each scenario. Scenario Three reduced the airborne time compared to Scenario Two (through ground delay), and provided slightly less delay overall. Note, ground delay in Scenario Three in an on-demand booking scenario (instead of scheduled service) would be reduced further by bookings being scheduled in accordance with the Flow Management Service requirements.
With the dedicated UAM corridors in Scenario Two, more predictable flight times were achieved than when only using the helicopter routes in Scenario One; the range in the standard deviations reduced by 0.6 minutes. Between Scenarios Two and Three (with Flow Management Services in addition to the dedicated UAM corridors), further predictability was achieved with the range in the standard deviations reduced by a further 1.5 minutes.

In Scenario One, based on the simulated traffic schedule 23 UAMs per hour would be transiting overhead Essendon. During the simulation, 25 aircraft needed to transit Essendon airspace with an arrival or departure taking place at Essendon, resulting in delays for those UAM operations. The human-in-the-loop simulations also concluded that a maximum of 4 concurrent UAM movements could be facilitated by Essendon under Scenario One conditions, which equates to 10 movements per hour. This is well below the 23 per hour evaluated in the fast time simulation.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Flight Count</th>
<th>Total Delay (minutes)</th>
<th>Average Airborne Delay (seconds)</th>
<th>Average Ground Delay (seconds)</th>
<th>Flight time std dev in minutes (range)</th>
<th>Throughput (per hour*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>92</td>
<td>61.8</td>
<td>40</td>
<td>0</td>
<td>0 - 2901</td>
<td>10</td>
</tr>
<tr>
<td>Two</td>
<td>84</td>
<td>6.8</td>
<td>5</td>
<td>0</td>
<td>0 - 1.401</td>
<td>41</td>
</tr>
<tr>
<td>Three</td>
<td>84</td>
<td>3.6</td>
<td>0</td>
<td>3</td>
<td>0 - 0.017</td>
<td>41</td>
</tr>
</tbody>
</table>

*Achievable throughput with human-in-the-loop simulation result constraints applied.

AIRCRAFT CONFLICTS

Table 7 shows the number of aircraft conflicts in each scenario. Scenario One produced the most conflicts between UAM vehicles and other aircraft due to overflying Essendon Airport and tracking along the helicopter routes. Scenario Three produced fewer conflicts than Scenario Two due to the flow management rules that regulate the flow of aircraft.

<table>
<thead>
<tr>
<th>Scenario One</th>
<th>Scenario Two</th>
<th>Scenario Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>UAM/ UAM vehicle</td>
<td>UAM/ non-UAM Aircraft</td>
<td>UAM/ UAM vehicle</td>
</tr>
<tr>
<td>Crossing</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>In-trail</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Opposing</td>
<td>12</td>
<td>29</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>54</td>
</tr>
<tr>
<td>Scenario Total</td>
<td>70</td>
<td>54</td>
</tr>
</tbody>
</table>
C.3.3 CONCLUSION

Scenario One (i.e. UAM operations using only the existing helicopter routes) created the most complex airspace due to a higher rate of conflicts between UAM vehicles and other aircraft (29% higher than Scenario Two and 80% higher than Scenario Three). These operations required a high degree of controller intervention and workload. Subsequently, implementing UAM operations solely through the use of helicopter routes is potentially challenging with the traffic volumes simulated.

Scenario Two provided dedicated flight corridors to segregate UAM operations from other Melbourne basin traffic. This resulted in:

- A reduction in the average flight time;
- An increase of UAM movements per hour due to traffic segregation achieved through flight corridors when compared to Scenario One;
- More predictable flight times with the range in the standard deviation reducing from Scenario One; and
- A reduction of UAM conflicts with other traffic in the basin when compared to Scenario One.

In Scenario Three, the benefits of introducing flow management along with dedicated UAM corridors resulted in:

- A reduction in the average flight time;
- A decrease in the average delay (by introducing ground delay) when compared to Scenario Two;
- More predictable flight times with the range in the standard deviation reducing from Scenario Two; and
- A reduction in conflicts when compared to Scenario One (without any dedicated UAM corridors).

Scenarios Two and Three showed similar results in terms of efficiency. However, in Scenario Three, the flow management-imposed ground delays led to a lower average flight time.

It is likely that in a more complex UAM network, flow management will provide greater gains. Close management of stands would also be required to ensure sufficient ground resources are available at the destination as this was a key constraint in the UAM network. Scenario Three had the least number of conflicts due to the regulation of arrival flows and route structures.

These results indicate that UATM Services could deliver potential benefits related to safety, flight efficiency, predictability and capacity.
## ANNEX D

### CONTRIBUTORS AND METHODOLOGY

<table>
<thead>
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<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
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<td>Contributors</td>
<td>93</td>
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<tr>
<td>D.2</td>
<td>Methodology</td>
<td>93</td>
</tr>
</tbody>
</table>
D CONTRIBUTORS AND METHODOLOGY

D.1 CONTRIBUTORS

This CONOPS was developed under a collaboration between EmbraerX and Airservices Australia. During the collaboration, EmbraerX and Airservices engaged the following stakeholders to improve the quality of information:

- Australian Civil Aviation Safety Authority (CASA);
- Australian Department of Infrastructure, Transport, Regional Development and Communications;
- Microlight, and
- Skyports.

EmbraerX and Airservices Australia are grateful for their contributions.

D.2 METHODOLOGY

D.2.1 CONOPS DEVELOPMENT

This CONOPS was developed using a three-step methodology as outlined below (Figure 20). A real-world use case was used (future Melbourne UAM operations) to assist in developing practical, implementable concepts; however, the intent was to develop concepts that could be globally applicable.

The primary activities occurred through several 3- to 5-day activities (face-to-face workshops and online workshops). Key concepts and activities were explored through several workshops that included internal Airservices and EmbraerX staff with expertise in the following areas:

- ATC operations specialists;
- ATM procedures and airspace designers;
- ATM flow management specialists;
- UAM vehicle developers;
- UTM technical experts;
- helicopter pilots;
- safety management and human factors specialists;
- government, community, airline and airport relations; and
- operational analysis, training and simulator experts.

At stages of the project, representatives from the government policy department and the regulator were involved in workshops.

Consultation with community, airline and airport stakeholders had been planned. Unfortunately, due to the COVID-19 pandemic, this was not possible.
STEP 1. CURRENT OPERATIONS BASELINING

The goal of baselining was to understand the environment in which UAM operations will be introduced. This included identifying the key services that are currently offered and future services that will be offered to UAM stakeholders. It also involved identifying UAM operational factors that will affect existing airspace, services and operations. Based on this and the objectives of UAM, a set of success metrics for UAM implementation were developed.

The following assumptions about other current aviation operations have been made in developing this CONOPS:

- As UAM evolves, traditional aviation will continue to evolve, including the increased use of technology and automation and greater performance capabilities (e.g. fuel efficiency, improved navigation capabilities, noise reduction).
- In the future, traditional aviation is likely to see operations involving both autonomous and pilot operations occurring at the same time.
- There will not be significant increases in the amount of ground infrastructure (i.e. runways) available at airports beyond what is already planned into the near- to mid-future but there will be significant development of infrastructure within cities to support UAM.
- The increasing levels of precision afforded by global navigation satellite systems combined with defined PBN specifications will reduce the volume of airspace required to contain routes and departure or arrival flight paths.

Output - A high-level view of new and impacted services, and a baseline set of safety, operational and business metrics for comparing UATM performance to today’s operations.
STEP 2: REVIEW OF INTERNATIONAL WORK

Based on the use case context, this step identified relevant international work that informed the concepts that were being generated.

**Output** - A report of key international activity and results relevant to the establishment of UATM concepts.

STEP 3: GENERATION OF CONCEPT OPTIONS

Concepts for a UATM system (i.e., airspace structures, procedures, services and technology concepts) were generated and refined.

**Output** - An initial CONOPS for UATM, including a description of

- key UAM elements,
- roles and responsibilities in UAM,
- an objective and description of each UATM Service,
- challenges with current operational capability to provide new UATM Services,
- the benefits of each UATM Service written in terms of performance expectations (using the ICAO KPAs), and
- how each UATM Service will grow in maturity over time.

Important considerations in the project were

- alignment of terminology;
- understanding of future UAM operations and relevant international work;
- understanding of current ATM procedures and technology and future ATM and UTM roadmaps;
- holistic consideration of all ICAO KPAs;
- near-term and long-term UAM operations, including voice-based piloted, autonomous and high-density operations; and
- an understanding of the implications of implementation.

D.2.2 CONOPS ANALYSIS, VALIDATION AND FEEDBACK

An important aim is to gain early insights into the feasibility and practicality of the proposed UATM concepts and align them with key stakeholder perceptions. Initial work has been undertaken to examine how UATM airspace design concepts will enable UAM operations and affect current operations. This data is also useful for identifying potential barriers and risks from UAM traffic growth. The results enable

- an understanding of capacity constraints and risks of introducing UAM operations,
- the testing of new airspace concepts and quantification of increase in capacity whilst maintaining or reducing levels of operational risk, and
- gaining of early insights from key stakeholders into UAM concepts.

Industry, government (political, policy and regulatory) and community groups will have a strong influence on the growth of the UAM industry. Without appropriate consideration, the growth of the UAM industry will be capped, thereby limiting the benefits of UAM to industry and society. A key aim of publishing this CONOPS is to understand stakeholder perceptions and needs, and thereby define system requirements giving consideration to those perceptions and needs. It also provides an opportunity to create awareness about the potential of future UAM operations.

Feedback on this CONOPS will inform future UAM implementation and UATM system design requirements. Furthermore, this information can help mitigate risks of rejection of UAM initiatives by industry, government and community.

Stakeholders are invited to provide feedback on this CONOPS through the Engage Airservices website, https://engage.airservicesaustralia.com/. All feedback received will be published on this site, along with answers to any questions.