UK AIR MOBILITY CONSORTIUM

URBAN AIR MOBILITY CONCEPT OF OPERATIONS FOR THE

LONDON ENVIRONMENT

MARCH 2022

A CAA Regulatory Sandbox Project

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DISCLAIMER

» The UK Air Mobility Consortium is pleased to share the following Concept of Operations with the UK and broader global aviation community, including industry, government, and the general public. The resulting body of work reflects significant collaboration across world-leading organisations including the UK's Air Navigation Service Provider, leading airports, air traffic management providers, aircraft manufacturers, and infrastructure companies. However, the following Concept of Operations should not be construed as representative of future plans of the Consortium member organisations, a request for proposal, or system requirements. All materials were written to help inform an industry position of the regulatory challenges facing Urban Air Mobility and propose various concept solutions to overcome them.

FEEDBACK

We recognise future refinement of the Concept of Operations will need to consider the perspective of all 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 Contact Us section of the Consortium's website ukairmobility.com where we will be happy to answer and discuss any questions.

FOREWORD BY UK CIVIL AVIATION AUTHORITY

UK Civil Aviation Authority

From its earliest days, aviation has always pushed the boundaries of technology and innovation. Always seeking to be faster, safer and now also more efficient and environmentally friendly.

The significant world-wide development of urban air mobility (UAM) in the past few years is again moving many of those boundaries into new and exciting territories. We are seeing multiple manufacturers gain significant financial backing to develop some exciting and promising aircraft.

These projects look certain to deliver electric vertical take-off and landing (eVTOL) aircraft into our skies in the very near future, bringing with it the potential for quieter, cleaner and more efficient services for passengers.

However, if the airspace and air traffic management systems aren't set to handle these new operations and the aircraft themselves don't have enough suitable landing sites, then this enormous potential and unique offering starts to be severely limited.

The good news is that, while of course there are complex issues to be overcome, there is no reason for this worst-case scenario to develop. This ground-breaking report describes potential ways in which a UAM concept could be safely integrated into one of the world's busiest cities with one of the world's most complex air traffic systems.

By actively involving many of the key players that would be required to make this a reality, it gives even more confidence that the task is achievable. I'm especially pleased at how well this project has involved so many leading stakeholders and engaged with my colleagues in the CAA. It has been a perfect example of why we set up our innovation sandbox. Enabling the expertise of innovators and the regulator to work together in a safe and open environment that then paves the way for more formal oversight and regulation. It is a shining example that, done effectively, regulation does not stymy innovation.

The significant detail in this report and its real-world scenario means it paves the way to make UAM a reality and its content will undoubtedly be of interest to the wider industry and other stakeholders considering the development of UAM.

Successfully achieving the roll out of UAM does though need more than regulation and infrastructure. Any form of aviation, especially flying in the urban environment, has a wider impact on the population and the rest of aviation. While eVTOL aircraft will deliver significant gains in noise and emissions it is important also to highlight the report's views that both the wider aviation community and those overflown should be included in any proposals.

We will continue to build on this principle and make sure regulators and innovators work together to deliver outcomes that safely push boundaries, delivering the sustainable aviation industry that we need for the future.

Frederic Laugere

Innovation Services Lead at Civil Aviation Authority

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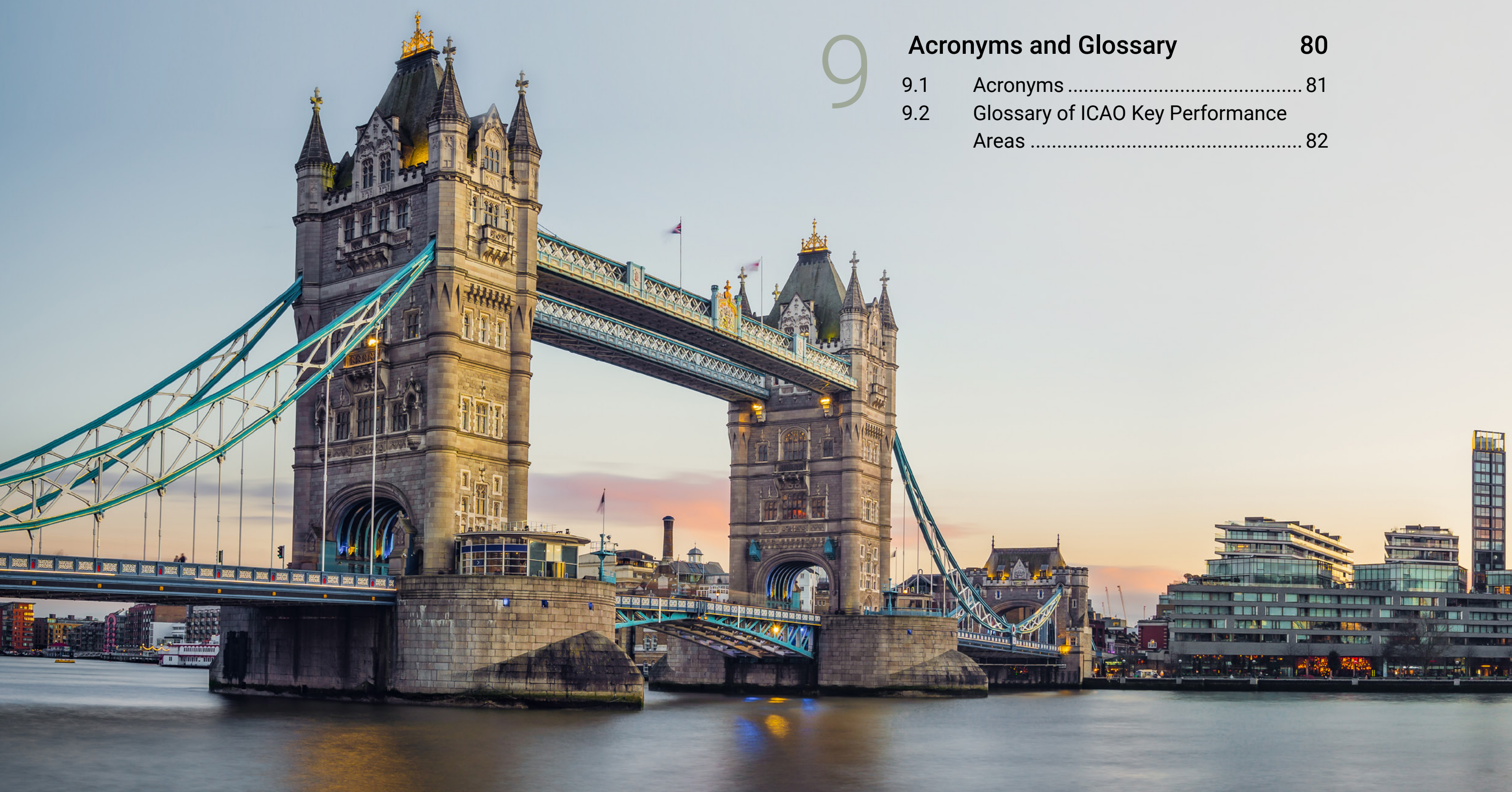

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INTRODUCTION

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1.1. PURPOSE

This thought leadership document, developed as part of the CAA Regulatory Sandbox Project, presents a model Concept of Operations (CONOPS) for safely integrating passenger carrying, piloted Electric Vertical Take-Off and Landing (eVTOL) aircraft into low-level airspace in the UK and establishing appropriate on ground infrastructure. The concepts developed in this document provides a framework for harmonising airspace, procedures, and infrastructure to accelerate the advancement of the Urban Air Mobility ecosystem validated through the contributions of world-leading aviation organizations as part of an Eve-led consortium, iterative reviews from the CAA Innovation Hub and respective subject matter experts, external stakeholder engagement, and simulations. The CONOPS is intended to support the CAA in shaping future regulations to support UAM operations across the UK.

The consortium worked in close collaboration and coordination with the CAA Innovation Hub to develop the CONOPS. In addition to Eve, the consortium includes international organizations that span the aviation industry and includes NATS, Heathrow Airport, London City Airport, Skyports, Atech, Vertical Aerospace, and Volocopter.

1.2. SCOPE

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

The document describes the likely phases of UAM operations from first introduction (with piloted, voice-based flights) through to mature, high-density autonomous operations, with the primary focus on how existing ATM procedures and technologies can be leveraged to support initial operations when eVTOLs are expected to enter service. The CONOPS emphasizes the importance of considering the future development horizons for UAM operations to ensure near-term approaches are aligned with the long-term goals of the proposed business case. This holistic approach to integrating UAM operations is important as both near and long-term objectives must be considered to minimise the amount of rework and cost at a later stage due to initial design decisions.

The use case developed to frame the CONOPS incorporates other airspace users, both existing and emerging, to support the fair and accessible access to airspace. This CONOPS is a technical document and for any operations to be sustainable and successful, it is recognised continued community engagement and consultation across all stakeholders will be essential for achieving a social license to operate. The consortium conducted preliminary stakeholder engagement for input and feedback on the concepts proposed. However not all stakeholders were included in the engagement activities, and all will need to be involved in future initiatives. This document acknowledges the importance of stakeholder engagement and their involvement in any future UAM operation design and implementation process.

1.3. CONTEXT

This CONOPS has been written to accommodate all types of vehicles, infrastructure and airspace classification that will be part of the UAM ecosystem. This ecosystem and environment will include eVTOL aircraft, helicopters, General Aviation (GA) aircraft, Remotely Piloted Aircraft Systems (RPAS[1]), airports, heliports, and vertiports.

The CONOPS has been designed following a London-centric use case established to derive the key regulatory challenges posed by the UAM business case and inform the concepts developed within the document. The concepts are intended for the broader UK environment through the application of CAA regulations to the proposed solutions. However, the concepts

[1]This document adopts the CAA terminology RPAS but can be used interchangeably with terminology used in other regions, such as Unmanned Aircraft System (UAS).

are designed to be globally applicable as UAM infrastructure, including traffic management systems, will need to be standardized so that products and services provided by government agencies and commercial organizations are consistent. Implementation of the concepts described in the document will be subject to policy decision by individual countries.

The UAM industry will continue to evolve. As such, this CONOPS is based on current knowledge and expectations of future UAM operations and is intended to help inform future activities of the CAA, other government agencies and the broader industry to mature the collective understanding about the design and implementation of UAM, such as vehicle specifications, traffic management solutions, and vertiport locations.

The document builds off other bodies of work with the intention to support the development of a globally harmonised approach. Specifically, content published in the Urban Air Traffic Management Concept of Operations developed through the EmbraerX and Airservices Australia collaboration to advance airspace integration concepts for UAM was used and leveraged in this body of work to inform the proposed concepts presented. The Eve-led consortium thanks Airservices Australia for their approval to use concepts developed and presented in the Urban Air Traffic Management CONOPS to support and advance the work in the CAA Regulatory Sandbox Project.

1.4. DOCUMENT STRUCTURE

This Concept of Operations is structured as follows:

Section 2	*Introduction to UAM Operations in Low-Level Airspace*	Introduces the key elements of UAM operations and low-level airspace to provide the foundational context for the CONOPS.
Section 3	*Current London Airspace*	Provides an overview of the current London Airspace with focus on the existing helicopter route structure with which future UAM operations will need to integrate.
Section 4	*Regulatory Challenges to UAM*	Introduces the UAM Use Case and the key regulatory challenges for integrating and scaling UAM operations within the London environment.
Section 5	*UAM Development Horizons*	Proposes a procedures-based evolution of UAM operations through Horizons on how and when the regulatory challenges will need to be addressed.
Section 6	*Concept Overview*	Introduces the UAM traffic management concepts, including an overview of both foundational and operational services that will support the introduction and scalability of UAM.
Section 7	*Concept of Operations: Horizon 1*	Provides a detailed CONOPS of how initial ATM procedures and technologies can be leveraged to support initial commercial UAM operations. Identifies key on ground considerations for Horizon 1.
Section 8	*Concept of Operations: Horizon 2*	Proposes a series of approaches for consideration when existing ATM procedures and technology are insufficient to support increased density and complexity of UAM traffic and new solutions are required. Identifies key on ground considerations for Horizon 2.

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SECTION 2

INTRODUCTION TO UAM OPERATIONS AND LOW-LEVEL AIRSPACE

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SAFELY INTEGRATING UAM INTO EXISTING AIRSPACE AND OPERATIONS, WITHOUT DISRUPTING OTHER AIRSPACE USERS, WILL REQUIRE A NEW WAY OF MANAGING AIRSPACE.

Conventional manned aviation is dependent either upon ATM services, or a pilot's ability to see and avoid other aircraft. As described below, UAM will perform differently from conventional aviation and, in the longer term, will have no pilot onboard to see and avoid other aircraft. The challenge is to reconcile these different ways of operation to enable all aircraft, crewed and uncrewed, to operate safely and efficiently in the UK skies. Electronic conspicuity, which ensures all types of aircraft will be seen and tracked, is essential to achieving this integration. Airspace modernisation is also key to a sustainable and efficient future for the national airspace infrastructure. The role of an airspace manager will remain critical in areas of busy airspace to ensure all aircraft are safely separated, and able to enjoy the benefits of an integrated and modernised airspace. To understand the impact of UAM on these challenges, it is important to first introduce how UAM will operate in low-level airspace.

This section describes the key elements of UAM vehicles, infrastructure, operations and low-level airspace that are important considerations for the UAM airspace integration concepts.

2.1 UAM VEHICLES

UAM vehicles are expected to primarily be electric Vertical Take-Off and Landing Vehicles (eVTOLs). In addition to electric designs, some Vertical Take-Off and Landing Vehicles (VTOLs) will be hybrid that use a combination of power sources. Helicopters will continue to be used as UAM vehicles but will likely be distinguished from eVTOLs due to some marked differences, including but not limited to noise, flight performance and safety considerations. UAM vehicles will be used to carry passengers and/or cargo.

UAM vehicles will have a range of performance envelopes. The general performance of electric aircraft, and in particular eVTOL aircraft vary from vehicle to vehicle. For UAM operations vehicles can be classified (at this stage) into one of three categories: vehicles with rotor-borne lift systems only, vehicles with vectored thrust and vehicle with both rotor-borne and wing-borne lift systems. In the latter two cases, vehicles make use of the rotor-borne or vectored thrust lift system for both the vertical take-off and landing phases of flight, but transition to and from wing-borne flight for the climb, cruise, and descent phases of flight. This is advantageous for vehicles required to perform longer range mission as wing-borne lift typically requires less energy per unit distance. Vehicles which have only a rotor-borne lift system make use of the rotor lift for all flight phases, which typically makes them better suited to shorter range missions.

EXAMPLE eVTOL CONFIGURATIONS

MULTIROTOR

Volocopter's VoloCity aircraft an all-electric multirotor eVTOL aircraft optimized for short-haul inner-urban missions. The flights distance is approximately 35 km and a cruise speed of 50 knots that allows convenient flights and the necessary manoeuvrability in an urban environment including adherence to more stringent obstacle limitation surfaces. The re-energizing concept includes a battery swap to ensure the highest level of safety and short turnaround times.

LIFT + CRUISE

Eve Air Mobility's aircraft is an all-electric lift plus cruise eVTOL aircraft, which uses 8 distributed rotors for take-off, hover and landing, and two rear propellers for the cruise phase of flight. The design is intended to deliver an energy efficient, quiet and quick cruise phase. Initial operations are planned for distances up to 100km at a speed of up to 110 knots. The vehicle range is intended to cover 99% of potential UAM missions.

TILT ROTOR

Vertical Aerospace's VA-X4 aircraft as an all-electric eVTOL aircraft capable of both rotor-borne operations as well as wing-borne cruise flight. As such, it has estimated cruise distances of up to 160km and a maximum cruise speed just over 175 knots. However, it should be noted that the typical operations will typically favour shorter routes flown at slower speeds as this allows for quicker recharge periods and more operational time, leading to reduced operating costs. At entry into service VA-X4 will be most profitable on routes up to 100km with a 10km divert at cruise speeds of around 130 knots once in wing-borne cruise flight.

IN THE NEAR TO MID-TERM, AND FOR THE SCOPE OF THIS CONCEPT OF OPERATIONS, UAM VEHICLES WILL BE PILOTED WITH THE PILOT ON BOARD.

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 structure-induced turbulence. 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). In the UK, operations under VFR will likely be limited and it is therefore assumed UAM vehicles will pursue capabilities to operate in IMC as soon as possible.

Urban flights will operate in proximity to buildings and highly populated areas for an extended proportion of flight time. When compared to flights today that use helicopters, these flights will operate at a much higher frequency and a greater density due to improved affordability, leading to greater demand. These vehicles will integrate with the existing Air Traffic Management (ATM) system and other airspace users (in particular, outside of controlled airspace) when operations commence.

CAPABILITIES OF EVTOLS

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 will be required 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 Mode S transponder and 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[2]. 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, but also others which differ. For example, eVTOL aircraft may have different limitations for wind speeds and directions for take-off and landing and also allow for new take-off and landing procedures.

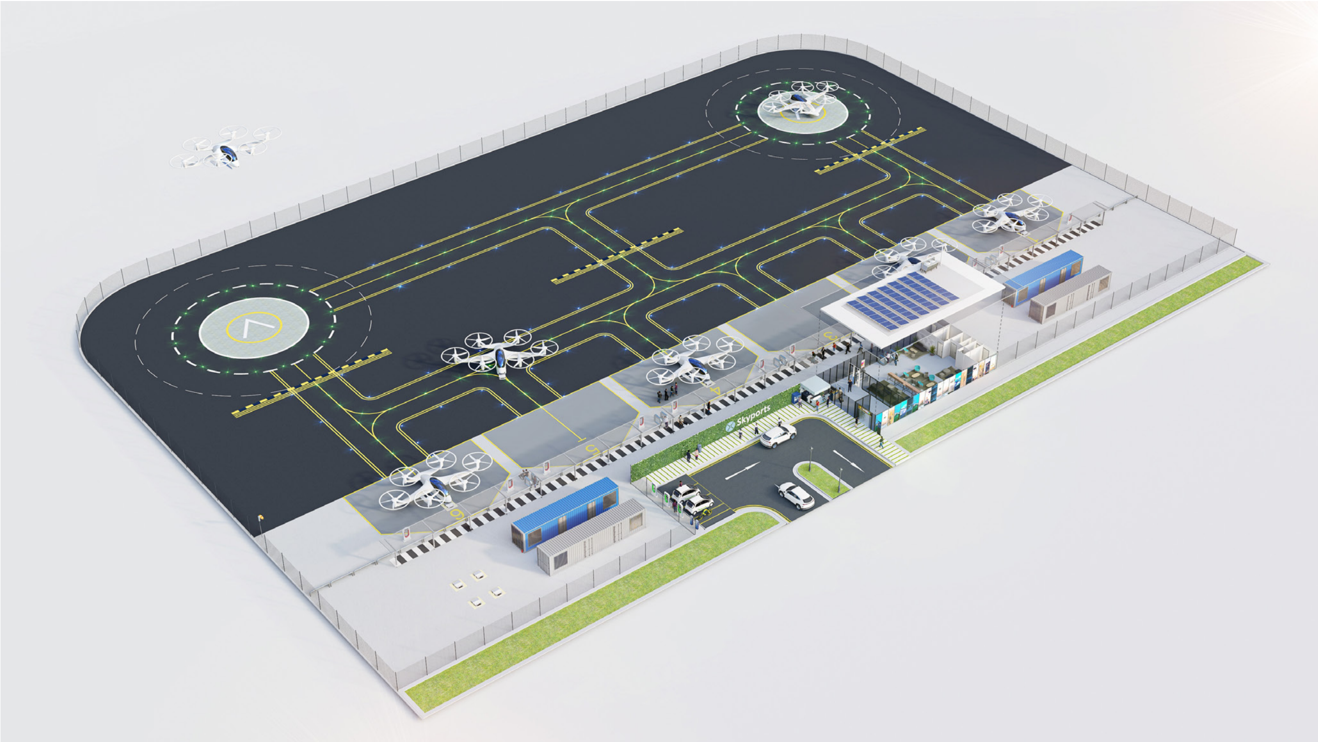
[2]This may also have implications for other types of aircraft operating in the same airspace.

DIFFERENCE 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 transition from rotor (or other vertical lift mechanisms) to wing-based flight for the cruise period of the operation, resulting in decreased manoeuvrability during the transition period when compared to helicopters as well as when operating as slower speeds.
- 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 eVTOLs operate, requiring eVTOLs to demonstrate equivalent levels of safety compared to the regulations and procedures used by helicopters today that will require new forms of energy management to address.
- As electric vehicles, eVTOLs will need time and facilities to recharge their batteries between most, 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 for the surface movement of VTOL aircraft to take off and land. A vertiport can have single or multiple UAM Final Approach and Take-Off Areas (FATOs) and Touchdown and Lift-Off Areas (TLOFs). A FATO is 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. In the UAM operating environment, there will be a mix of vertiports with single or multiple FATOs. The TLOF functions as the dynamic load-bearing area upon which the VTOL may touchdown and lift-off and is usually collocated in the FATO; a vertiport should have at least one TLOF[3]. The TLOF may also be collocated with a VTOL aircraft stand. Where there is surface movement of the VTOL aircraft between a FATO and a stand, a ground taxiway and ground-taxi route will be required. Where space at the vertiport permits and depending on the distance between the FATO and the TLOF (when they are not collocated), an air taxiway and air taxi route would be required to enable the movement of the VTOL aircraft above the surface between the FATO and the stand.

There may be just one vertiport for a local urban area or many vertiports within a local urban area operated by different organizations (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. 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. 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. Movement between a FATO

[3]In this CONOPS the term FATO is used with the inclusion of a collocated TLOF within the FATO.

and a TLOF (when not collocated) or between a FATO and TLOF (when collocated) and a stand will occur while the vehicle is on the ground (either towed or using ground movement equipment (GME) or taxied) or in a low hover using ground and air-taxi routes and taxiways.

Vertiports will be equipped with the necessary infrastructure to support different operation conditions. As is the case for all aerodromes, they will require navigation aids/appropriate lighting (or equivalent solutions), and corresponding procedures to enable safe flight operations for its intended hours of use and, if required, all weather capabilities including instrument approach procedures. 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.

Different vertiport configurations will support different throughputs. It is expected vertiport capacity will affect the capacity of the overall system, particularly in the early stages while there are few vertiports. Vertiport capacity will largely depend on the number and throughput of the FATO provided at each site as well as the number of stands. This capacity will be impacted by aircraft ground handling processes and vehicle capability, including:

- FATO occupancy time (arrivals)
- FATO occupancy time (departure)
- Departure and arrival profiles
- Wake turbulence interaction and separation
- Noise abatement or other specific airspace procedures required at the vertiport
- Turnaround time

2.3 OVERVIEW OF UAM OPERATIONS

UAM OPERATING ENVIRONMENT IN LOW-LEVEL AIRSPACE

UAM vehicles will operate in low-level airspace both within and outside of the urban environment. UAM vehicles are expected to operate primarily between 500 ft – 1,000 ft AGL, but they will also operate above this level. Operating at this height has benefits from an energy consumption perspective, but (as discussed later) may also provide benefits for segregation from other aircraft.

UAM vehicles will integrate with other airspace users. Other airspace users, including helicopters, RPASs and fixed-wing aircraft, will also use low-level airspace. In the future, there will be a 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.

The UAM vehicles will cruise above the majority of RPAS operations, which are expected operate in the majority below 400 ft AGL. However, some RPAS are expected to operate above 400 ft AGL and UAM vehicles will operate in the same airspace as RPASs during approach and departure and around vertiport locations, where flight paths need to exist at lower altitude.

Depending on the flight path and destination, UAM vehicles will need to transit through what is currently categorized as controlled and uncontrolled airspace. Initially, UAM operations will take advantage of existing VFR routes, transition routes[4], or existing helicopter procedures, if deemed appropriate for eVTOL performance capabilities.

UAM operations may operate at a higher tempo than current low-level operations. In addition to an increased exposure to the risk of controlled flight into terrain, high-tempo operations at low altitudes in an urban environment will also expose vehicles to a greater risk of mechanical turbulence from surrounding structure (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 routes will be planned for UAM vehicle operations. Conversely, there will be some portions of 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 Temporary Reserved Airspace (TRA), Temporary Danger Area (TDA) or Restricted Area (RA(T)). Traditional airspace users will periodically need to use airspace that is planned primarily for UAM vehicle operations.

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

[4] A Transition Route is defined as a specific flight course to transitioning controlled airspace (e.g., Class B). Transition Routes include specific ATC-assigned altitudes, and pilots must obtain an ATC clearance prior to entering controlled airspace along the route.

NOMINAL (STANDARD) FLIGHT

A UAM vehicle departs from a vertiport FATO toward another vertiport FATO. A 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 based on either repetitive or ad hoc flight plans will include interaction with the UAM vehicle pilot and/or 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 in some use cases hover for a period over certain locations (e.g., tourist flights).

OFF-NOMINAL (NON-STANDARD) FLIGHT

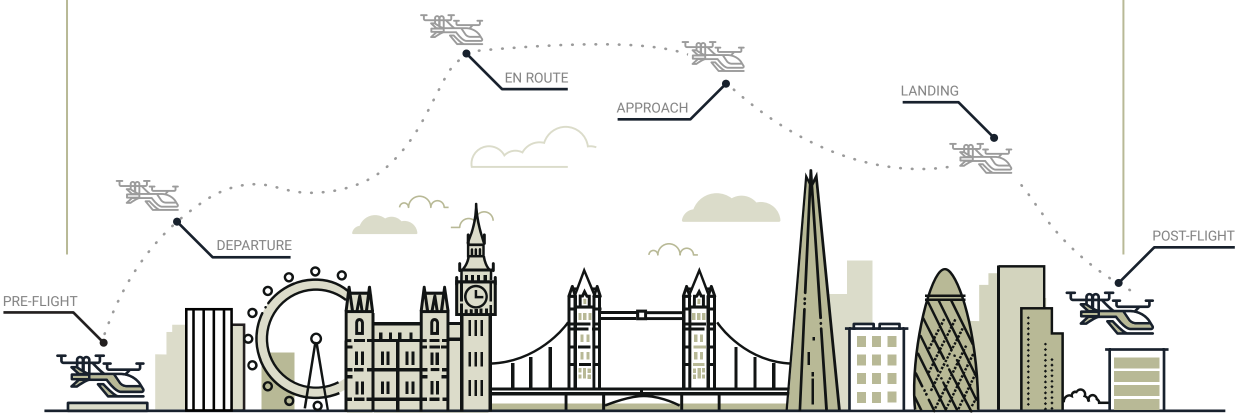
A UAM vehicle must be capable of Continued Safe Flight and Landing. However, a UAM vehicle may need to change vertiport destination due to onboard reasons such as technical system failure, passenger/pilot issues, or changes in operational requirements. An off-nominal situation may also arise from external 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.

In addition, changes to airspace access, such as TRAs or RA(T) 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.

UAM FLIGHT PHASES DEFINITIONS

- **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 collocated with a TLOF and stands are provided) 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 alternative 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 (if the FATO and TLOF are collocated) or ground or air 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.



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2.4 OVERVIEW OF UAM OPERATIONS CONCEPT DEVELOPMENT AROUND THE WORLD

Other Concepts of Operations have been developed or are currently in development around the world. These concepts of operations introduce specific considerations and assumptions which are important to identify as they might influence international operating standards, global operating rules, vehicle certification and stakeholders' processes. Concept of Operations of particular interest, which are referenced to varying degrees within this document, include:

- NASA UML-4 UAM Concept of Operations (NASA CONOPS UML-4)
- FAA Urban Air Mobility Concept of Operations v.1.0 (FAA CONOPS 1.0)
- Airservices Australia and EmbraerX Urban Air Traffic Management Concept of Operations

SECTION 3

CURRENT LONDON AIRSPACE

3.1 London Helicopter Route Structure 21

THE LONDON CTR AND LONDON CITY CTR CONTROL ZONES ARE CLASS D, MEANING THAT AN ATC CLEARANCE IS REQUIRED TO ENTER THE AIRSPACE.

Instrument Flight Rules (IFR) and VFR flights are permitted, and all flights are provided with air traffic control service. IFR flights are separated from other IFR flights and Special VFR (SVFR) flights, receive traffic information in respect of VFR flights and traffic avoidance advice on request. SVFR flights and SVFR flights are separated from each other unless prescribed otherwise and agreed by both pilots (SERA.8005(b)(4) & (5)). VFR flights receive traffic information in respect of all other flights and traffic avoidance advice on request. Continuous air-ground voice communications are required for all flights (EASA, 2018).

Note: *The London CTR is defined as a [Mode S] Transponder Mandatory Zone (TMZ).*

3.1 LONDON HELICOPTER ROUTE STRUCTURE

Current helicopter operations utilise published/procedural VFR routes to operate within the London CTR (see Figure 1). This section will describe the main characteristics of these routes and assess their suitability for applicable UAM operations.

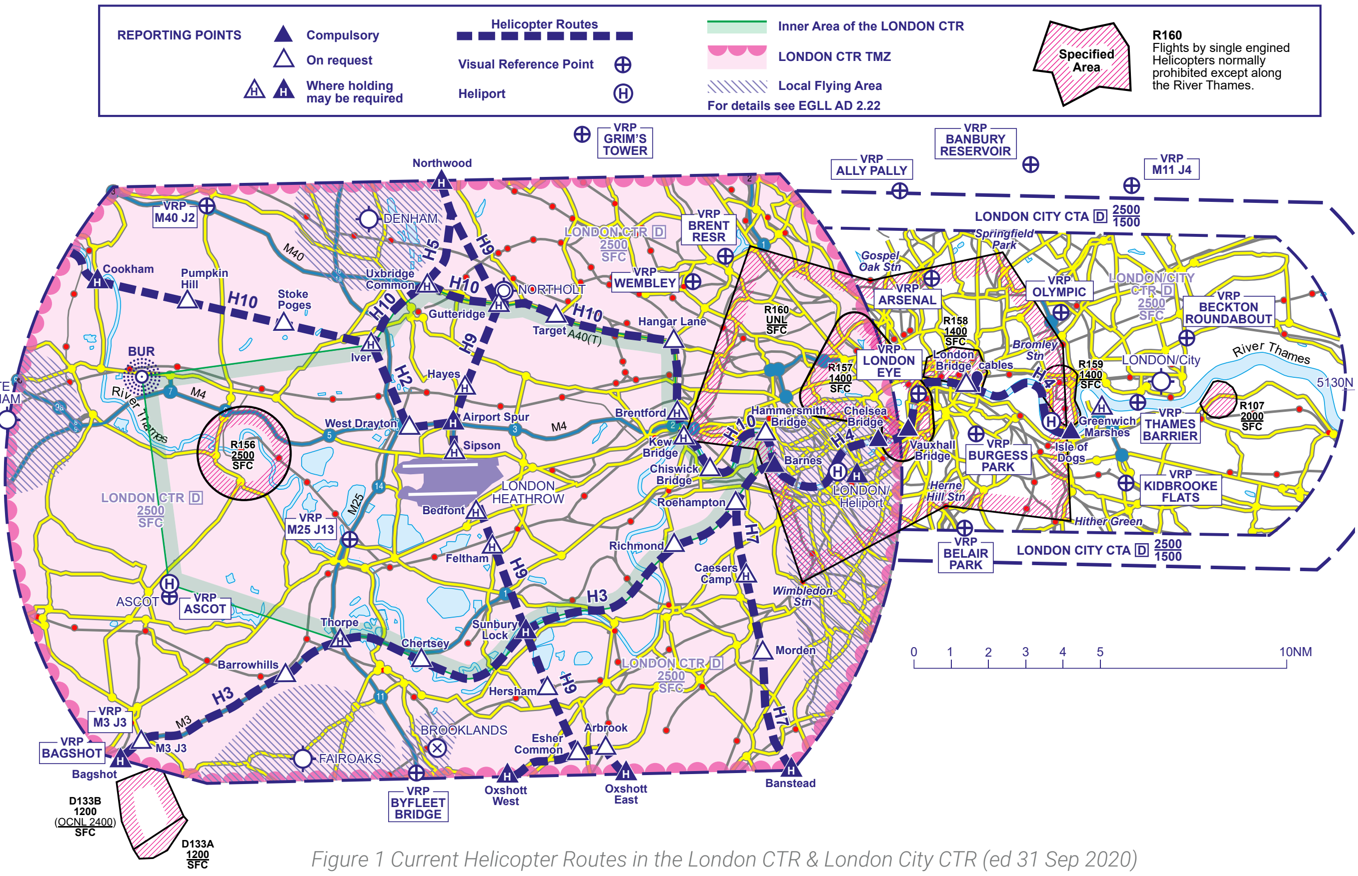

Figure 1 Current Helicopter Routes in the London CTR & London City CTR (ed 31 Sep 2020)

The existing VFR route structure is characterised by two routes running approximately West – East to both the North (H10) and South (H3) of Heathrow Airport. Both routes converge to join a published route (H4) that follows the course of the River Thames through Central London to the Isle of Dogs. These routes enable transits to/from Central London to the West. There is provision to link these key axes from both the North (H5, H9) and South (H7, H9) Additionally, a route (H9) exists to facilitate a North-South transit over the top of Heathrow Airport. These existing routes are utilised by a range of rotorcraft traffic, from commercial helicopter services to/from Battersea Heliport, helicopters transiting London N-S to avoid lengthy diversion around London airspace, military flights (e.g., those in/out of RAF Northolt) and Police and HeliMed (HEMS) operations.

The routes are published according to Visual Flight Rules (VFR) and thus the composition of the route structure is defined according to line features (such as roads, railways, rivers) that facilitate navigation by visual means. The structure of the routes is underpinned by Visual Reference Points (VRPs) and Reporting Points (RPs), again defined by notable physical/geographical features that can be identified visually, such as motorway junctions. Over time, these types of procedures may not be suitable for UAM operations.

In addition to the published route structure, helicopters are permitted to operate off route following ATC authorization. A considerable amount of the helicopter and fixed wing traffic in the London CTZ operates off route.

***Note**: provision is made for Special VFR when applied within a CTR; thus 'VFR flight' within the London CTR may be performed accordingly to SVFR provisions. For ease of readability, this document may use 'VFR flight' to mean SVFR when operating within a CTR.*

VFR flight for helicopters is performed in Visual Meteorological Conditions (VMC), within the London CTR (i.e., controlled airspace) this means:

- Maximum speed limit of <140KIAS.
- By day: clear of cloud, surface in sight, minimum 1500m visibility. Remain clear of cloud and in sight of surface.
- At Night: minimum 1500m/1000ft from cloud, minimum 5km visibility, surface in sight.
- Aircraft operating SVFR have 1000m visibility minima on the Helicopter route structure and 800m off it.

These minima appear applicable/proportionate for eVTOL aircraft, noting that the minimum flight visibility for helicopters would likely apply (it being a function of the ability of such aircraft to fly more slowly, and even hover, in reduced visibility conditions).

The existing VFR route structure takes into account some mitigation in the event of critical loss of powerplant(s) in that, distinct visual line features, such as rivers, will typically be the least developed/populated areas within what is characteristically an overwhelmingly dense urban environment. Such a mitigation is acceptable based on a rotorcraft's ability to perform an autorotation (controlled management of rotor RPM to facilitate controlled landing) in the event of a critical loss of powerplant (engine failure). An assumption of this CONOPS is that eVTOL developers will be able to satisfy the regulatory authorities with regard to safe landing following critical systems loss, potentially using alternative approaches to autorotation.

In general, VFR flight has no specified separation minima against other VFR traffic, with pilots instead employing the 'see-and-avoid' principle outlined in the Single European Rules of the Air (SERA) to ensure collision detection and avoidance is achieved by remaining 'well clear' of other traffic. However, it is important to note that Class D controlled airspace is a known traffic environment and therefore ATC has a legal requirement to notify the VFR pilots of all other aircraft that may operate in proximity of each other in order to assist the pilot to apply 'see-and-avoid' principles.

ATC may instruct aircraft to fly to the north or south side of the river in order to be procedurally separated from traffic on the opposite side of the river (when operating SVFR). Aircraft may deviate from the centre of the river as far as required providing the requirements of SERA.3105 Minimum Heights and SERA.5005 Visual Flight Rules can be complied with (NATS, 2019).

BACK TO MENU

SECTION 4

REGULATORY CHALLENGES TO UAM

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4.1 PROPOSED USE CASE

For intra-urban flights, UAM would operate entirely within the London CTR (surface to 2500ft) and London City CTR if transiting as far east as the Isle of Dogs. The proposed use case will examine piloted, passenger carrying flights connecting a small network of 4 vertiports spanning Heathrow Airport (LHR) to London City Airport (LCY) with intermediate stops including City of London and White City. The network will provide flexibility where possible with options for passengers to take direct flights between each of the locations (e.g., City of London to London Heathrow Airport).

Taking into consideration published/procedural VFR routes to operate within the London CTR, potential eVTOL routings have been considered to connect the network of 4 vertiports. eVTOL flights are planned to rely on one-way routings except when close to landing or departure sites, to optimise route utilisation and mitigate collision risks.

Key considerations when planning eVTOL routings include:

i) Restricted areas, R157, R158 and R159 will need to be avoided as far as practicable (unless permission is gained).

ii) Routes will need are to be assessed against obstacle clearance rules of 1,000ft over parts of London although it is assumed that some areas may receive dispensation from this allowing the application of only the 500ft rule (as per the London Helicopter Routes).

iii) R160 regulations still apply.

iv) Flights can take place outside controlled airspace for a small portion of total duration.

v) Flights transit between 500 - 1,000ft AGL (subject to appropriate UK aviation rules).

vi) Flights will be deconflicted by some means along the routes.

vii) eVTOL routes are not co-located with the existing helicopter route structure and the number of intersections between eVTOL and helicopter routes are minimised where possible.

viii) Access to the London Heliport ATZ is to be avoided.

Whilst existing procedures are adequate for current [low numbers of] helicopter operations and initial UAM applications, such as the intra-urban 'Airport Shuttle', three factors may challenge the ongoing suitability of the route structures and accompanying procedures, if:

i) forecast demand for UAM operations increases as expected.

ii) forecast traffic of other airspace users, including manned, increases dramatically.

iii) the level of automation of rotorcraft and/or UAM aircraft increases beyond the point of predominant manned operations to widescale autonomous operations.

Should one or more factors occur, new airspace requirements, routes and associated procedures will need to be developed.

4.2 REGULATORY CHALLENGES

The proposed use case introduces a number of regulatory challenges that must be overcome if to be successfully achieved. The following regulatory challenges, which focus on those related to airspace integration and are therefore not exhaustive relative to the broader challenges related to the introduction and scalability of UAM, were grouped into three high-level areas:

- Scaled UAM Operations
- Low-level flying in congested urban airspace
- Performance and capabilities of eVTOL aircraft

The focus for initial operations (introduced as Horizon 1 in Section 5) is to demonstrate equivalent levels of safety to that of manned aviation, as they are subjected to the same regulatory regime. For instance, the ability of a piloted eVTOL aircraft to be accepted as being at least equivalent to the ability of a pilot of a manned aircraft to 'see and avoid' potential conflicts. However, there should also be latitude within early operations to exhibit new technology in real world environments to demonstrate the safety and operational benefits they will bring and therefore flexibilityin the relevant regulations, subject to the normal regulatory oversight, is of paramount importance.

4.2.1 Scaled UAM Operations

The use case proposes scaled UAM operations, ultimately increasing the traffic density of the target airspace environment. This would include multiple UAM fleet operators operating in what is currently urban Class D airspace; specifically, the use case considers route through central London spanning from LHR to LCY.

The theoretical number of movements across the four vertiport locations presented in the use case is estimated to be upwards of 520 flights per day, even in a "low traffic" scenario.

For comparison, over the last 5 years the number of low-level flights within the London and London City CTRs has been around 25k movements per annum, with the busiest day being 214 movements in the last 12 years.

The proposed increase in traffic within the London and London City Control Zones (CTRs) presents major operational, safety and integration chalwlenges to overcome.

Fundamental to this aspect of the use case is the ability to manage a complex network of traffic flows and to maintain equitable access to airspace.

HUMAN PERFORMANCE COMPLEXITIES IN NETWORK MANAGEMENT

The proposed traffic levels could create additional complexities for air traffic management which may consequently make deconflicting traffic flows more complex and require more mitigations to maintain the level of risk of incidents and accidents.

CONTEXT OF EXISTING REGULATIONS:

- ICAO Annex 11 currently assumes ATC has a responsibility to prevent collisions between known flights in controlled airspace.
- However, for VFR traffic in controlled airspace, it is the operator who has the responsibility to see and avoid which becomes more difficult in more dense traffic scenarios.
- ATC will provide sufficient information to all VFR operators to safely integrate their flight with other aircraft.

FAIR AND EQUITABLE ACCESS TO AIRSPACE

At the proposed traffic levels the use case challenges the principle of providing fair and equal access to the proposed airspace. Specifically causing a possible (or perceived) disruption to the current status quo and 'Share the Air' principles for Class D airspace users (noting Class D is the construct of the current airspace) I.e., the principle that when flying under VFR aircraft should have equal access to Class D airspace on a first come first served basis.

CONTEXT OF EXISTING REGULATIONS:

- The underlying principle of Class D airspace is that airspace users are expected to share the air.
- References include the UK ATS Airspace Classifications, as derived from the Single European Rules of the Air (SERA) classification system, CAP 774 UK Flight Information Services, and CAP 493 Manual of Air Traffic Services Part 1.

4.2.2 Low-level Flying in Congested Urban Airspace

The use case proposes the operation of UAM vehicles in low-level airspace for operational reasons (height is preferred for vehicle efficiency). UAM vehicles will climb to a preferred AGL between 500 and 1,000ft with the ability to operate at higher altitude as necessary. Vehicles will be operating under a large range of meteorological conditions, both VMC and IMC. Vehicles may use existing helicopter routes (if approved) but will also likely need to operate outside of these due to operational and customer requirements.

Fundamental to this aspect of the use case is the need to understand the risk of operating in a range of weather conditions, within the obstacle environment, in close proximity to other aircraft operations and to minimize the impact of the operation on communities on the ground.

FLIGHTS WITHIN OBSTACLE ENVIRONMENT

The proposed low-level operations pose a risk of collision with permanent and temporary obstacles, of controlled flight into terrain and of loss of control induced collisions. Current Target Levels of Safety (TLS) are designed for operations above the obstacle environment. Operating within the obstacle environment would result in a fundamental change of approach for the TLS, as established in Procedures for Air Navigation Services – Aircraft Operations (PAN OPS Doc 8168).

To consider a change to the current ruleset, risk assessments would need to be carried out to ensure that all risk areas associated with low flying can be controlled to an acceptable level. In light of such assessments, regulators may consider and determine any new applicable TLS for such scenarios.

CONTEXT OF EXISTING REGULATIONS:

- ICAO Annex 11 and specific consideration to the references to the applicable SERA, under section 2, should be given.
- Dependent on specific operational factors the rule for flying in congested areas is to fly no lower than 1000ft above the highest obstacle within 600m. There are some exceptions within the London and City CTRs (primarily for helicopters operating on the notified routes) but it would need to be determined if these could also apply to some or all types of UAM aircraft.
- Similarly, under the same ruleset, aircraft usually "must not be flown closer than 150 meters (500 feet) to any person, vessel, vehicle or structure except with the permission of the CAA.
- CAA UK wake turbulence categories database [10].
- SERA, CAP493 Section 1 Chapter 4.
- Global safety reports and databases.
- CAP1864 (for helicopter accident causes within the London CTR).
- PAN OPS Doc 8168.

ENABLING VISUAL AND INSTRUMENT METEOROLOGICAL CONDITIONS (VMC & IMC) OPERATIONS

UAM only operating under VFR may work for initial operations but will quickly limit predictability and service availability for this use case. Given the limitation of IFR flights operating below about 2,000ft neither IFR or VFR provide a complete framework under required operational meteorological conditions to support regular operations.

The use case proposes that UAM vehicles will operate under VFR similarly to other VFR flights in controlled airspace (Class D under the current UK airspace structures) and that they will also seek to fly in Instrument Meteorological Conditions (IMC) in controlled airspace without additional burden on ATC. The intention to seek an IMC operation, at the scale of traffic and altitudes proposed, poses an increased risk of collisions.

For flights to operate safely at low altitude in a range of weather conditions, obstacle clearance and separation minima would need to be considered.

Operations in IMC are currently conducted under IFR; Current rules governing flight in IFR do not provide a viable framework to support the operations described in the use case – specifically given the restriction associated with altitude and separation minima.

CONTEXT OF EXISTING REGULATIONS:

- ICAO Annex 11 and SERA rules prevent the proposed low-level flight on grounds of terrain and buildings avoidance.
- SERA 5015(b)(2) applies regardless of location; aircraft must be 300m above an obstacle within 8km (unless specifically authorized by the CAA).
- ENR 1.3 instrument flight rules.
- SERA.6001.
- CAP493 Section 2.

SOCIAL LICENCE

Social licence is the ongoing approval from stakeholders for products, services, business practices and operations. As the nascent market for UAM develops, gaining social acceptance and support for the new technologies - and particularly public services - is recognized as key to future success. For the use case, the combination of low-level flight and traffic density raises these questions.

The noise, privacy, and visual intrusion implications of low-level operations will need to be understood, considering the effect on communities on the ground. Specific consideration would need to be given to communities in the vicinity of vertiports. Both day and night operations would need to be considered.

CONTEXT OF EXISTING REGULATIONS:

- Airspace Change Process (ACP) CAP1616 - Community consultations may be required under the ACP. Where an airspace change is likely to be required, engagement should start at the beginning of the regulatory process.
- CAP19000 Social Licence to Operate: Concept Guide for New Technologies.

FLIGHT IN CLOSE PROXIMITY TO OTHER LOW-FLYING TRAFFIC

The proposed low-level operations poses risks associated with flying in close proximity to other low flying traffic (such as RPAS operations and helicopters). Regarding operations by RPAS, many of these flights currently take place up to 400ft AGL, without notification, flight planning, surveillance or the provision of ATS. There are considerations regarding the proximity of the proposed UAM operation to RPAS traffic and consequently in controlling the risk of mid-air collision or accidents due to avoiding action.

The close proximity of helicopters, primarily those flying outside of established heli-routes, increases the inherent risk of mid-air collision and other accidents induced by loss of control or taking avoiding action. This will require thorough assessment and appropriate mitigation, considering the ability of UAM vehicles to make-way for and avoid other traffic when required. Specific focus should be given to the ability to make way for National Police Air Services (NPAS) and Helicopter Emergency Medical Services (HEMS) (and other flights with the appropriate flight priority category), as required under the rules of the air.

CONTEXT OF EXISTING REGULATIONS:

- CAP722
- Reference to existing helicopter route structure
- Reference to HEMS and NPAS flying off route

4.2.3 Performance and Capability of eVTOL Aircraft

The use case proposes the operation of new types of aircraft (UAM Vehicles) where UAM Vehicles are expected to be eVTOL aircraft and hybrids that use a combination of power sources. The UAM vehicles will be used to carry passengers and/or cargo. Depending on the vehicle design, eVTOLs will have different manoeuvrability capabilities than helicopters in different flight phases depending on their unique design considerations and configurations, i.e. may be less manoeuvrable than helicopters at slower speeds and during the transition period from rotor to wing-based lift. Based on near/medium-term battery technology projections, eVTOL will not be able to hover/hold for as long as a helicopter and reduced endurance is a key characteristic that will constrain eVTOL operations.

Fundamental to this aspect of the use case is the vehicle's limited endurance whilst in the cruise phase of flight.

IMPACT OF DEVIATING FROM FLIGHT PLAN

The performance capabilities of eVTOLs, specifically endurance and manoeuvrability will need to be considered in planning approaches to tactically responding to a variety of safety critical scenarios. One of the biggest challenges facing eVTOL aircraft is the low gravimetric energy density of existing battery technology. Currently and initial operating period, eVTOL aircraft endurances may not match those offered by their conventionally powered counterparts, and certainly cannot meet the reserve endurance requirements in place today.

A related battery challenge is the limitation on energy transfer rates both in to and out of battery cells. Allowable charge and discharge rates are linked to battery size and battery state of charge. Batteries with greater capacities will allow faster charge and discharge rates, proportional to their size increase over batteries with smaller capacities. A key enabler for eVTOL aircraft to be successful is the need to charge quickly – ideally, no longer than the passenger turn-around event duration. For these reasons operational efficiency is optimised by only partially charging the battery before a flight with just enough energy for the flight, plus diversion energy, plus any mandatory reserve, as well as enough energy to allow for the high energy landing event at the end of the mission.

As with traditional aircraft, the degree of deviation from flight plan whilst in-flight will need to be based on rules that accurately and precisely account for proven aircraft endurance/ capabilities. Consideration will need to be given to the ability of UAM operations to respond to real-time changes to flight plan and specifically deviations which elongate flying time/distance outside of the vehicle's endurance limits. Such scenario may include deviations for e.g.:

- **Traffic avoidance** and specifically the ability to make way for National Police Air Services (NPAS) and Helicopter Emergency Medical Services (HEMS) (and other flights with the appropriate flight priority category), as required under the rules of the air.
- **Weather avoidance** including procedures in reaction to receiving a severe space weather event (CAP1428).
- **Compliance with ATC instructions** (e.g., in Class D airspace there is a requirement to be able to receive ATC instructions, to respond accordingly and receive traffic information including routing instructions, visual holding instructions, level instructions and information on collision hazards which shall be avoided).
- **Other disruptions to the traffic flow** including e.g., disruptions in efficient flows of traffic in the airspace and on approach and departure and provide suitable airspace or ground infrastructure.
    - For eVTOL with wide variation in speeds, loiter times and performance, separation and operational resilience / vehicle insurance / energy reserves will need to be maintained.
    - The variation in aircraft performance such as approach speeds will make it challenging for managing separations between aircraft and provide suitable airspace or ground infrastructure.
    - The limited range and diversion capabilities of eVTOLS may lead to challenges in finding suitable alternate vertiports when airspace issues affect large numbers of aircraft simultaneously.

CONTEXT OF EXISTING REGULATIONS:

- SERA
- CAP493 Section 1 Chapter
- ICAO Annex 14 vol 2

4.3 OTHER CONSIDERATIONS

The use case poses a number of challenges that are not directly related to airspace integration, but which may be important to consider as part of the broader roadmap for implementing UAM. This section includes some of these broader considerations, focused on areas the Consortium would like to highlight. Such considerations are outside of the scope of the CONOPS but may have implications which need to be considered, as appropriate, while addressing the challenges previously defined.

The various considerations discussed within this section are not comprehensive and include evolving discussions. The content should not be read as final or agreed.

4.3.1 Airspace Policy

The current airspace policy is largely defined by existing aircraft, airspace, airspace classification system and airport operations. As discussed later in document, the regular and dynamic introduction of new UAM routes that will be necessary to scale operations will require quick changes to routes across large swathe of low airspace environment, where there are existing operations by other aircraft. This suggests that the current airspace and airspace classification system may need to be adapted for the longer-term growth of the industry.

CONTEXT OF EXISTING REGULATIONS:

- Airspace policy alone may facilitate some aspects of UAM trials and operations, as well as adaptations to routes over time, avoiding any requirement to carry out an airspace change.
- The existing airspace change process CAP1616 process was principally designed for local airspace changes for commercial aviation but is also used to apply airspace changes across large swathes of airspace. At the time of writing, CAP1616 is being applied to two airspace changes simultaneously - to introduce Free Route Airspace at high altitude (above FL245), and on London Airspace Modernisation Programme to change the airspace between 7,000 ft and 24,500ft.
- However, the current airspace policy and the interlinked CAP1616 does not readily lend itself to the progress of UAM airspace trials and eventual operations over an extended period of time in a low airspace environment such as London.
- It is understood that CAP 1616 is undergoing a review at the moment and therefore there is an opportunity to take account the requirements of UAM and other BVLOS applications.

4.3.2 Vertiport Operations and Viability

With regards to the regulatory challenges of airspace integration, vertiport operations are not a focus. There are some specific airspace integration considerations which will discuss the interface between the landing site and the airspace, but these are tackled in other challenges.

It should be noted that international and national design standards for vertiports do not exist currently. EASA are producing Prototype Technical Specifications (PTS) for the design of VFT vertiports for operation of manned aircraft with VTOL capability certified in the enhanced category, which are expected to be published in early 2022. In March of 2022, the FAA published interim design standards for vertiports in the form of an Engineering Brief, ahead of a performance-based Advisory Circular (AC) expected in 2024. Similarly, standards for vertiport operations,anticipated when use for commercial passenger and/or public transport VTOL flights, do not exist currently; however, standards development organisations, particularly EUROCAE, are in the process of developing guidance for vertiport operators and operations for piloted VFR VTOL operations, which could be employed as a means of developing a licencing/regime for vertiports.

Design and operational standards for aerodromes and heliports are not fit for purpose to enable the performance requirements of VTOL aircraft. Existing Obstacle Limitation Surfaces (OLS) requirements for heliports, if applied to vertiports, would:

i) restrict the introduction of vertiports and UAM into constrained urban.

ii) undermine the full suite of performance capabilities of VTOL aircraft. In addition, aerodromes, including heliports when there are scheduled flights, that are used for commercial passenger and/or public transport flights, must be licensed. However, existing heliports should be considered and allowed to be used by VTOL aircraft as only minor modifications (such as FFRS) may be necessary.

The development of regulations and standards will define the capability of vertiports for normal and abnormal operating conditions. To enable the timely introduction of vertiports, in urban areas in particular, in support of commercial VTOL aircraft operations, the regulator will need to develop (in partnership with industry) the design and operational requirements for vertiports to ensure safety in the context of VTOL aircraft performance.

CONTEXT OF EXISTING REGULATIONS

- ICAO Annex 14 Aerodromes, Volume II Heliports, prescribes the physical characteristics and obstacle limitations surfaces (OLS) to be provided for heliports, and provides a foundation from which to develop vertiport design standards.
- Vertiports will be designed in line with emerging UAM vehicle specifications e.g., EASA SC VTOL.
- The use case proposes to provide at least one approach and departure path. ICAO Annex 14 Aerodromes, Volume II Heliports requires heliports to have at least one approach and take-off climb surface. In line with ICAO it is expected that for vertiports a single approach and take-off climb surface will need to be provided following the completion of an aeronautical study by an appropriate authority that considers the following factors:

  i) the area and terrain over which the flight is being conducted.

  ii) the obstacle environment surrounding the vertiport.

  iii) the performance and operating limitations of the VTOL aircraft intending to use the vertiport; and iv) the local meteorological conditions, especially prevailing winds. The UK deviates from ICAO in this instance and requires at least two approach and take-off climb surfaces.

- Vertiports will be designed for eVTOL aircraft; however, existing heliports could become vertiports where doing so would support safe eVTOL aircraft operations or a mixed operation of helicopter and eVTOL aircraft operations only to the extent where the standards for vertiports are equivalent or exceed those of heliports. Any vertiport design/regulation/certification will require engagement from multiple different stakeholders operating under different regulatory bodies and rule sets.
- CAP 168 sets out the standards required at National licensed aerodromes, including heliports within the scope, relating to management systems, operational procedures, physical characteristics, assessment and treatment of obstacles, visual aids, rescue and fire-fighting services and medical services.

4.3.3 Vertiport Planning and Safe Guarding

National planning policies and how these are expected to be applied at the local level do not recognize the concept of vertiports and route structure. This would make it difficult for vertiport developers to receive planning consent and for owners and operators to safeguard vertiport operations from future development. To enable the timely development of vertiports, government planning policy and guidance to Local Planning Authorities (LPA) will need to recognize and define the concept of a vertiport within the NPPF.

Enshrining the vertiport concept in national planning policy and guidelines, with an explicit recognition of the importance creating and maintaining a network of vertiports, will also help vertiport owners and operators safeguard their assets and operations from future development.

The noise and visual intrusion implications of low-level operations will need to be understood, considering the effect on communities on the ground. Specific consideration would need to be given to communities in the vicinity of vertiports. Both day and night operations would need to be considered.

CONTEXT OF EXISTING REGULATIONS:

- National Planning Policy Framework (NPPF) (2019), If the vertiport is subject to planning permission, the local planning authority will undertake a period of public consultation where views on the proposed development can be expressed. Public consultation will take place regardless of whether an ACP requiring community consultation is required, as the land use planning and airspace change processes are exclusive.
- Airspace Change Process CAP1616, Community consultations are required under the ACP and so such challenges are of heightened importance to consider.

SECTION 5

UAM DEVELOPMENT HORIZONS

THE UAM DEVELOPMENT HORIZONS DEFINED IN THIS CONOPS DESCRIBES THE EVOLUTION OF UAM FROM TRIALS AND INITIAL, PILOTED OPERATIONS THROUGH TO FULLY AUTONOMOUS OPERATIONS.

The CONOPS will examine regulatory challenges associated with initial commercial operations (Horizon 1) and transition to medium-density operations (Horizon 2) where new procedures and technology will be required to support UAM operations. The introduction of autonomous operations (Horizon 3) is described in this section as it is a key industry driver for achieving a sustainable large scale UAM industry and therefore an important future reference point when defining the Horizon 1 and 2 concepts.

The regulatory challenges introduced in Section 4 will impact the introduction and scalability of UAM operations at different times. Due to the low-level traffic volumes expected in Horizon 1 and use of current procedures, some regulatory challenges will not arise until Horizon 2 while other challenges will evolve. The approach to addressing these challenges across the Horizons defined will be iterative and continuously evolve requiring an agile approach.

The growth of operations across the Horizons is expected to support the development of a social license for UAM operations overtime and is explored in more detail later in the document.

Operating environments across the UK will experience the Horizons at different stages with overlap occurring depending on the maturation of the different use cases.

HORIZON 0	HORIZON 1	HORIZON 2	HORIZON 3
Trials	**Low-density**	**Medium-density**	**High-density**
UAM trials to support the safety case for initial operations using the existing framework.	initial operations with piloted UAM vehicles using conventional ATM procedures and technologies.	UAM operations where current ATM procedures and technologies are insufficient to support the demand for operations.	UAM operations with piloted and autonomous UAM vehicles supported by new ATM services.

HORIZON 0 (TRIALS)

The objective of Horizon 0 is to develop evidence to support the safety case for initial operations using the existing airspace structure, procedures, and technology. A trial phase will be required prior to the introduction of commercial operations of piloted eVTOLs. The trial phase will focus on defining the foundational elements that must be in place prior to commercial operations being able to begin. A number of preparation activities will need to occur in this phase, including:

- Gathering of aircraft performance data for the planned UAM aircraft.
- Review of and the necessary updates to the air traffic services regulatory framework, such as relevant CAP documents and procedures, as well as clarification on aircraft type and separation minima.
- Development of ground infrastructure including vertiport design and planning, charging stations, vehicle services and support facilities.
- Management of social acceptance with specific stakeholders prior to first flights.

These activities are discussed more holistically in later sections of the document.

Trials will be conducted in a Sandbox environment of increasing levels of complexity to test and prepare for initial commercial operations. *Note: The processes needed to commence trials prior to commercial operations will be addressed by other bodies of work and is outside of the scope of this CONOPS.*

HORIZON 1

Horizon 1 will include the introduction and initial increase of piloted eVTOLs and vertiports for low-density, commercial operations. Horizon 1 will occur after Horizon 0, the trial phase of UAM operations prior to any commercial operations. Trials will still occur during Horizon 1 with a focus on the new procedures and technologies necessary to move beyond limitations of existing framework.

The first UAM operators will start regular commercial operations using existing airports and heliports, as well as purpose-built vertiports. Operations will increase at different rates, with new operators entering into service at different times and the development of new vertiports requiring the use of new flight paths.

Commercial operations will use conventional ATM procedures and technologies in Horizon 1. This may include the development of new procedures using existing rules. Horizon 1 eVTOL operations will only fly in VMC conditions following existing VFR procedures.

Operations will occur within a small network of vertiports flying, where appropriate, on bespoke routes (similar to current helicopter routes) for eVTOLs in unsegregated airspace. Initial integration within the airspace will allow UAM operations to be in close proximity with other low-level airspace users (e.g., helicopters, RPAS, etc.).

Horizon 1 is loosely equivalent to NASA's UML 2 - Low Density and Complexity Commercial Operations with Assistive Automation, with early adoption of some UML 3 capabilities with the minimum level of systems, procedures and regulations required to support initial commercial RPAS flight operations.

Horizon 1 will address the following regulatory challenges defined in Section 5:

- Flights within obstacle environment
- Social license
- Flight in close proximity to other low-flying traffic
- Impact of deviating from flight plan

By following current procedures and using existing technology, the following regulatory challenges will not be addressed until Horizon 2 due to low-traffic levels and operations occurring only in VMC under existing VFR:

- Human performance complexities in net work management
- Fair and equitable access to airspace
- Enabling VMC and IMC tailored to UAM operations

HORIZON 2

Horizon 2 will occur when current ATM procedures and technologies are insufficient to support demand of medium-density, piloted UAM operations. Increase in demand will require new ATM procedures and/or technologies that are not currently used by ATM and will introduce new UAM traffic management services to support UAM operations. These services will vary in service type and maturity, from initial procedures and services to full implementation.

Multiple UAM operators will share the airspace and supporting ground infrastructure within a growing network of vertiports operated by a variety of organizations. New vertiport locations will be introduced at an increased frequency and incorporated into a growing UAM operating environment. Vertiports introduced in Horizon 2 will increase in complexity with more FATOs and stands to support increased demand.

Operations will occur with a range of environmental conditions under both VMC and IMC. Integration within airspace will evolve from Horizon 1 allowing UAM operations to continue to be in close proximity with other low-level airspace users.

A mature Horizon 2 is loosely equivalent to NASA's UAM Maturity Level 4 – Medium density and complexity operations with collaborative and responsible automated systems.

Horizon 2 will face new regulatory challenges and some regulatory challenges encountered in Horizon 1 will become more challenging and require matured approaches to overcome. New challenges that will be faced in Horizon 2 include:

- Human performance complexities in network management
- Fair and equitable access to airspace
- Enabling VMC and IMC tailored to UAM operations

The regulatory challenges first addressed in Horizon 1 that will become more challenging are:

- Social License
- Flights within obstacle environment
- Flight in close proximity to other low-flying traffic

HORIZON 3

Horizon 3 will see high-density UAM operations with piloted and autonomous UAM vehicles supported by UAM traffic management services. New vertiport locations will be dynamically introduced and incorporated into a growing and flexible UAM operating environment.

Note: Horizon 3 is outside the scope of this CONOPS. However, it is important to consider this future state to mitigate risk of developing concepts that will restrict UAM from being able to evolve towards autonomous operations.

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SECTION 6

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THIS SECTION PROVIDES AN OVERVIEW OF THE UAM OPERATIONAL CONCEPT FOR AIRSPACE INTEGRATION AND INCLUDES SUBSECTIONS ON EACH OF THE SERVICES THAT WILL BE REQUIRED TO SUPPORT UAM OPERATIONS.

The concepts introduced in this section will be applied in greater detail to the Use Case to provide a roadmap for scaling UAM operation from Horizon 1 to Horizon 2, including a transition period between the two horizons.

A set of services supports the achievement of UAM airspace integration in London. Two foundational services to prepare the UAM operating environment for operation:

- **Airspace and Procedure Design**
- **Information Exchange**

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

- **Flight Planning and Authorization**
- **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 during Horizon 1. The maturity of these services will evolve as UAM traffic complexity or density increases. Each service will evolve in maturity at a pace proportional to the growth of operations; I.e., some services will achieve higher levels of implementation maturity sooner while others remain more basic. The necessary operational services and their level of implementation maturity at each UAM development horizon will depend on the unique needs of each airspace environment.

Though the six services are presented separately, they will require increasing levels of integration to support UAM operations as density and complexity increases.

6.1 AIRSPACE AND PROCEDURE DESIGN

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

The service will take into account the unique nature of UAM vehicle and operator 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 and clearance into controlled airspace.
- Design and implementation of defined UAM routes within unsegregated controlled airspace and the procedures that minimize 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 classification of airspace or reclassification of existing airspace to accommodate increased density of UAM operations.
- Safe and effective integration of UAM operations, providing deconfliction 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.
- Procedures for emergency, severe weather, and off-nominal operations.

PERFORMANCE EXPECTATION/BENEFITS (IN ICAO KPA TERMS[5])

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

- **Safety** - Pre-flight 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 maximize 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, in air holding, and more direct routes.
- **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 defined airspace structures and routes. Limiting use of dedicated corridors reduces/minimizes impact on access to airspace for existing and other emerging airspace users.
- **Participation and collaboration** - Provision of a structure means by which new vertiport infrastructure can be considered.
- **Global interoperability** - Standardized structures and procedures for the UAM industry used in different countries.

As a foundational service, Airspace and Procedure Design will be highly influential in overcoming all identified regulatory challenges:

- Human Performance Complexities in Network Management.
- Fair and Equitable Access to Airspace.
- Flights with Obstacle Environment.
- Enabling Visual and Instrument Meteorological Conditions (VMC & IMC) Operations.
- Social License.
- Flight in Close Proximity to Other Low-Flying Traffic.
- Impact of Deviating from Flight Plan.

[5] A glossary of the ICAO KPA Terms, as defined in the ICAO Global Air Traffic Management Operational Concept document (Doc 9854) is provided at the end of this document.

6.2 INFORMATION EXCHANGE

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 services to support safe and efficient operations.

Information Exchanged must be aligned with ATM information management principles as far as is practicable[6]. 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 supporting UAM traffic management systems, 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. UAM traffic management 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 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 regards 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 harmonized digital data standards.

The specific information that will be exchanged and by which stakeholders to support initial operations is provided in Section 7.2.2.

[6]As defined in ICAO. (2005). Global air traffic management operational concept (Doc 9854).

PERFORMANCE EXPECTATION/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 bases 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.

As a foundational service, Information Exchange will be highly influential in overcoming all identified regulatory challenges:

- Human Performance Complexities in Network Management.
- Fair and Equitable Access to Airspace.
- Flights with Obstacle Environment.
- Enabling Visual and Instrument Meteorological Conditions (VMC & IMC) Operations.
- Social License.
- Flight in Close Proximity to Other Low-Flying Traffic.
- Impact of Deviating from Flight Plan.

6.3 FLIGHT PLANNING AND AUTHORIZATION

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

A flight authorization is the clearance for a UAM flight, the flight plan and a reservation for vertiport use. Where the provision of UAM traffic management services is mandated, all UAM operations will require a flight authorization. Flight planning requires a centralized 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 Authorization Service to enable scaled operations beyond what can be accommodated by current ATM procedures and technologies 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.

PERFORMANCE EXPECTATION/BENEFITS
(IN ICAO KPA TERMS)

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

- **Safety** - Pre-tactical deconfliction of UAM vehicle movements near vertiports and along routes.
- **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 airspace capacity and vertiport resources to maximize capacity.
- **Flight efficiency** - Timed use of vertiport FATO resources and use of defined routes minimizing 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.

Based upon this benefits analysis, Flight Planning and Authorization will support overcoming the following regulatory challenges:

- Human Performance Complexities in Network Management.
- Fair and Equitable Access to Airspace.
- Enabling Visual and Instrument Meteorological Conditions (VMC & IMC) Operations.
- Social License.
- Flight in Close Proximity to Other Low-Flying Traffic.
- Impact of Deviating from Flight Plan.

6.4 FLOW MANAGEMENT

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 maximize 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 maximize airspace capacity, Flow Management will use 4D trajectories, which will consider vertiport departure and arrival times and be assessed as part of airspace authorization decisions.

PERFORMANCE EXPECTATION/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 minimizes the amount of energy that needs to be consumed.
- **Capacity** - Ensures that the greatest capacity is achieved from the available vertiport infra-structure and airspace structure.
- **Flight efficiency** - Minimizes the time reduced 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 operation al 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 vertiport and airspace.

Based upon this benefits analysis, Flow Management will support overcoming the following regulatory challenges:

- Human Performance Complexities in Network Management.
- Fair and Equitable Access to Airspace.
- Social License.
- Flight in Close Proximity to Other Low-Flying Traffic.
- Impact of Deviating from Flight Plan.

6.5 DYNAMIC AIRSPACE MANAGEMENT

The objective of the Dynamic Airspace Management Service is to maximize the performance of low-level airspace and its structure as environmental and operational needs shifts. 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 vary from predictable to unpredictable. Flight Planning and Authorization 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 authorizations, including those already in flight, must be reviewed to determine how the chances affect the flight plans and whether the existing flight authorizations need to be cancelled or amended.

Dynamic airspace and/or defined routes/corridors can:

- Provide strategic separation of aircraft, increasing available capacity.
- Share aircraft noise to prevent concentration over one community.
- Ensure business continuity for fleet operators and vertiports.

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

PERFORMANCE EXPECTATION/BENEFITS (IN ICAO KPA TERMS)

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

- **Safety** - Minimizes airspace safety risks 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 prioritization of airspace access.

Based upon this benefits analysis, Dynamic Airspace Management will support overco-ming the following regulatory challenges:

- Human Performance Complexities in Network Management.
- Fair and Equitable Access to Airspace.
- Social License.
- Flight in Close Proximity to Other Low-Flying Traffic.

6.6 CONFORMANCE MONITORING

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 authorization. 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 UAM 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.

PERFORMANCE EXPECTATION/BENEFITS (IN ICAO KPA TERMS)

An effective Conformance Management 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. Systemic awareness provides information to assist in supporting future safety cases.
- Efficiency - Known historical use of airspace provides information to assist in improving future use.

Based upon this benefits analysis, Conformance Monitoring will support overcoming the following regulatory challenges:

- Human Performance Complexities in Network Management.
- Enabling Visual and Instrument Meteorological Conditions (VMC & IMC) Operations.
- Social License.
- Flight in Close Proximity to Other Low-Flying Traffic.
- Impact of Deviating from Flight Plan.

SECTION 7

CONCEPT OF OPERATIONS: HORIZON 1

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THE OBJECTIVE OF HORIZON 1 IS TO GAIN POLITICAL AND SOCIAL ACCEPTANCE AND GENERATE DATA DRIVEN CONCLUSIONS TO SUPPORT THE SAFETY CASE FOR NEW AIRSPACE STRUCTURES, PROCEDURES AND TECHNOLOGY THAT WILL BE REQUIRED FOR HORIZON 2.

Achieving Horizon 1 operations is not the objective or end in itself, but rather a necessary step for entering into Horizon 2 as the capacity limitations of Horizon 1 are unlikely to support the business case set forth by industry. It is also not the intention to reach the capacity limitations of the existing airspace structure, procedures and technology in Horizon 1 to prove the transition to Horizon 2 is necessary. Reaching and sustaining operations at the maximum capacity of the existing airspace structure, procedures and technology in Horizon 1 may be detrimental to the social and political acceptance of UAM and place additional burden on ATC. It is therefore important to prepare for entry into Horizon 2 in parallel to Horizon 1 operations to support incremental increases in traffic volumes through new airspace structures, procedures and technology.

7.1 HORIZON 1 REGULATORY CHALLENGES

In this the section the considerations for Horizon 1 regarding the regulatory challenges introduced in Section 4.2 are described.

7.1.1 Low-level Flying in Congested Airspace

7.1.1.1 SOCIAL LICENCE

Due to the low flying nature of eVTOL aircraft, it will be important to achieve a social license for UAM prior to commencement of commercial operations in Horizon 1. The social licence will need to factor in the potential future growth in UAM operations in Horizon 1 and future horizons.

Social licence should be achieved in combination with and using existing formal legal and regulatory processes and permissions, including airspace change processes and infrastructure planning. Regulatory and legal processes to secure planning permission for vertiports and changes to airspace will be subject to compulsory stakeholder and community engagement and consultation.

A social licence will require positive and constructive engagement across stakeholder groups that have influence. Social licence will need to be developed and maintained for technology and operations that are unfamiliar, complex and subject to a high-degree of change. Gaining a social licence will require communication efforts that include informing stakeholders about UAM, its potential effects on communities, and its benefits. It will also require planning of operations and infrastructure to be changed in response to relevant and reasonable input and feedback.

7.1.1.2 FLIGHT IN CLOSE PROXIMITY TO OTHER LOW-FLYING TRAFFIC AND WITHIN THE OBSTACLE ENVIRONMENT

Operating at low levels in an obstruction rich environment limits the ability to manoeuvre to avoid obstructions or other aircraft, increases pilot workload, and reduces time available to react to incidents. The airspace design and UAM operations planning must consider the risks of flying at a low level in close proximity to other traffic and obstacles in Horizon 1.

The airspace and procedures design and UAM vehicle operations planning should include mitigations to address any additional or increased risks related to UAM operations. Airspace and procedures design safety assurance will address:

- The risk of incidents and accidents because of loss of control in flight (LOC-I), controlled flight into terrain (CFIT) and mid-air collision (including risk to third parties).
- The wake turbulence interactions of flying in a closely spaced and mixed-use airspace close to tall buildings.
- Avoidance of obstacles.
- Integration with RPAS, particularly near vertiports.

Individual vehicle operator and manufacturer safety assurance will also address:

- The risk of incidents and accidents because of loss of control in flight (LOC-I), controlled flight into terrain (CFIT) and mid-air collision (including risk to third parties).
- Pilot performance (e.g., ability to maintain lateral separation from other traffic, to take avoiding action and make way for priority traffic).
- eVTOL aircraft performance (e.g., the manoeuvrability of eVTOL aircraft and the ability to avoid obstacles, other traffic and make way for priority traffic).

A significant consideration in Horizon 1 operations (and later Horizons) is the approach to integration or segregation from other aircraft operations. Integration (rather than segregation) will ensure the skies remain accessible to all types of airspace user and all types of operation, but will increase the challenge of mitigating flying in close proximity to other low-flying traffic.

7.1.2 Performance and Capability of eVTOL Aircraft: Impact of Deviating from Flight Plan

7.1.2.1 GENERAL EVTOL PERFORMANCE BACKGROUND

The eVTOL aircraft performance capabilities are expected to remain consistent through Horizons 1 and 2 although technology innovation will continue leading to evolution in performance capabilities. The variety in vehicle type and capabilities is expected to increase over time. Some UAM operations further into the future may benefit from increased performance characteristics due to improvements in battery technology. Given the long lead time for vehicle certification, Horizon 1 will primarily address currently known, in development eVTOL aircraft performance capabilities. Performance, particularly with regard to continued safe flight and endurance are a key part to supporting any safety case for regulatory amendment and is expected to remain true throughout each Horizon.

7.1.2.2 IMPACT OF DEVIATION FROM FLIGHT PLAN

In the event of non-standard operations where a deviation from flight plan is expected, the effects depend on the type of deviation:

- If a deviation occurs during the en route phase of flight and if the new en route distance is same or less than previously planned, the deviation is not complicated from an energy management perspective.
- Procedures for managing more complex deviations where additional distances may be required must be developed prior to operation.

7.2 SUPPORTING INITIAL COMMERCIAL OPERATIONS THROUGH EXISTING FRAMEWORKS AND SYSTEMS

This section describes the planning, design and operational considerations for Horizon 1. It uses the conceptual framework defined in Section 6 as a structure to address key areas relating to traffic management and vertiport planning. Further consideration of ground operations is provided in the next section.

7.2.1 Airspace and Procedures Design

The objective of Airspace and Procedure Design 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 following areas will be of key consideration in Airspace and Procedures Design for Horizon 1:

- Airspace structure and use of airspace
- Vertiport location planning
- Vertiport licencing
- Airspace Change Process
- Integration with UK Airspace Modernisation Strategy

7.2.1.1 AIRSPACE STRUCTURE AND USE OF AIRSPACE

It is expected that in Horizon 1, the initial flights of UAM vehicles can be accommodated within the existing airspace environment, but that wider deployment from Horizon 2 onwards will require a more fundamental airspace change. The key concept for airspace structures in Horizon 1, is that the use of existing risk mitigations not currently deployed should be assessed for their benefit to support UAM operations both in Horizon 1 and future horizons. Some risk mitigations may be temporary in nature to bridge the gap to future risk mitigations in Horizon 2, while others may support future operations through to scaled and even autonomous operations. A number of existing risk mitigations are discussed below that may be used in support of Horizon 1 operations and may be increasingly needed as volume and complexity of operations grow.

» Use of Transponder Mandatory Zones

Increased situational awareness in the skies will be especially important when UAM vehicles have different flying characteristics from the manned and unmanned ones they operate alongside – for example flying lower or higher, slower or faster. An example of existing risk mitigations that could be assessed is the use of Transponder Mandatory Zones (TMZs). TMZs ensure that all aircraft operating within its boundaries are electronically conspicuous, i.e., all types of aircraft can see, be seen and avoid others. This is key to enabling the safe integration of UAM outside controlled airspace.

The London CTR is a Mode S TMZ; however, the London City CTR is not and there are no current plans to change this. However, the majority of airspace users in the London City CTR are already equipped with a Mode S Transponder.

The CAA has recently concluded a consultation in April 2021 on alternative forms of electronic conspicuity data, for example ADS-B, within a TMZ, to permit suitably equipped aircraft to access that airspace and take an ATC service (either in the form of Flight Information Service of Air Traffic Service) as appropriate to the airspace classification.

» Route Structures

To enable predictability of airspace use for UAM operators and other airspace users, in Horizon 1 it is expected that UAM vehicles will follow defined routes in unsegregated airspace. This will be especially relevant in this London use case and would enable the transformation of the busy lower airspace into a more predictable working environment. Some operations may be able to commence without a route structure being in place.

There is currently no safety analysis to enable new UAM vehicles to make use of the existing published/procedural VFR routes within the London and London City CTRs. Initial operations will potentially be more effectively enabled by the design and implementation of defined UAM-specific routes (which are unsegregated) in and outside controlled airspace rather than the use of existing Helicopter routes.

Further systemisation can exploit existing ATM capabilities, such as advanced performance-based navigation (PBN), to fully optimise the route network. In this way, position routes can be designed according to where they are needed operationally, without being constrained by the location of conventional ground-based navigation infrastructure.

Local procedures for local holds, joining and landing instructions, circuits, and go-arounds for each vertiport will need to be established. A further enablement is hence the adaptation of ATC flight procedure design, with the aims of reducing complexities and potential bottlenecks created by existing airspace structures, while holistically considering airspace and ground safety risks. A data-driven approach will be adopted, with risks assessed through techniques such as quantitative Collision Risk Modelling. UAM routes should be designed as close to ICAO 'PANS-OPS' design criteria for existing manned aircraft as practicable, in the absence of UAM-specific procedural design regulations and standards.

For Horizon 1 UAM routes would be defined, which would allow aircraft to fly between 500 and 1,000ft AGL, similar to current VFR routes in London used by helicopters. Routes will be dependent on vertiport locations and need to factor in the planning processes associated with vertiport location selection. Similar to the creation of the current London helicopter route structure, locations of suitable open areas in which to land in a Continuous Safe Flight and Landing case and in an emergency, taking into account the performance characteristics of UAM vehicles, should be considered when planning routes.

7.2.1.2 VERTIPORT LOCATION PLANNING

It is expected that vertiports away from airports will be established in Horizon 1. A vertiport that is not an existing aerodrome will require approval before development by the local planning authority. In addition, the vertiport operator may need to obtain permission from the CAA through an airspace change to alter the use of airspace around the vertiport.

The local planning authority will be a local council within whose administrative boundaries the vertiport is located. Applications may be raised by regional government, e.g., London Mayor, or central government depending on the 'strategic importance'. Decisions will be made in accordance with planning legislation, namely the National Planning Policy Framework, and planning practice guidance, as well as in consultation with local communities. Current planning legislation and guidance does not recognise the concept of a vertiport; therefore, local planning authorities will be expected to potentially not be supportive of projects to establish vertiports, the nature of which is not understood or articulated as an established concept at the national level.

7.2.1.3 VERTIPORT LICENSING

It is likely that vertiports used for commercial passenger flights and/or public transport passenger flights, will be legally required to be licensed by the regulator. When UAM traffic is light, eVTOL aircraft carrying single passengers or groups of passengers booking together and travelling at unscheduled times to a destination of their choosing, could be classified as a charter operation. Unlicensed vertiports could service a charter operation.

Where eVTOL aircraft carry more than one person, where tickets for flights on the same flight are sold separately and where the passengers cannot dictate the final destination, vertiports are expected to be licensed to safely accommodate these types of operations. The regulator will likely determine the minimum standards required at a licensed vertiport, including management systems, operational procedures, physical characteristics, assessment and treatment of obstacles, visual aids and rescue and fire-fighting services and medical services. Continued inspections by the regulator are expected to guarantee requisite safety standards are maintained.

7.2.1.4 AIRSPACE CHANGE PROCESS

For UAM operations to take place in the United Kingdom within a new defined Airspace Structure, the UK Airspace Change Process (CAP1616) will need to be followed. Any Horizon 1 Airspace Changes would be evolutionary in nature, given the expected development of the industry to Horizon 2.

The 7-stage Airspace Change Process takes time to implement, depending on the scale and permanence of change. For UAM, it is considered one of the more complex or controversial proposals, as the process needs to consider evolving technology in vehicle and traffic management while keeping pulse of changes in public acceptance. Based upon the indicative timeframe for aircraft achieving certification in the middle of the current decade, the need to begin the CAP1616 process will be relatively soon. The option of an Airspace Trial could be instigated which would allow initial operations to commence and, concurrently, the Airspace Change Process could commence. Dependent on the Airspace Trial agreement and subject to a regular review and approval, it is possible that the Airspace Trial could "roll over" until the permanent Airspace Change was approved and implemented.

7.2.1.5 INTEGRATION WITH UK AIRSPACE MODERNISATION STRATEGY

The UK Airspace Modernisation Strategy (AMS) presents an opportunity for the changes associated with UAM to be integrated with other airspace change and presents the possibility of a smoother transition pathway into Horizon 1 and/or Horizon 2. It is expected that smaller changes in airspace design required for Horizon 1 could be achieved separately from the AMS; however, to achieve Horizon 2, would require significant integration with the UK AMS due to their scale and significance.

UAM was not an identified AMS requirement but with a review and publication of a revised AMS in January 2022[7], UAM and other future technologies have been included in the initiatives. The AMS has been re-mobilised and sponsors are restarting or recommencing their respective airspace changes to facilitate the relevant initiatives – this includes a review of low-level operations within the LTMA and the extent of Controlled Airspace. It is important that UAM is recognised in the AMS, so that sponsors could potentially incorporate UAM into their respective airspace changes as early as possible.

[7]CAP1711: Airspace Modernisation Strategy (caa.co.uk)

7.2.2 Information Exchange

This section describes some of the key information exchange that will occur in Horizon 1, accommodated by existing systems and planned investments/evolutions.

Aeronautical Information

Like other aircraft operations, fleet operators and pilots will need to have access to airspace data to plan their flight operations. This airspace data will include charts, procedures, aerodrome/heliport/vertiport data, sectorization, aeronautical information publications, terrain and obstacle information. In Horizon 1 it will be necessary to have specific meteorological information related to the vertiport. In the urban area, temporary special user airspace will be necessary for emergency/security operations creating restrictions/constraints to the regular operation. Like other aircraft operations, fleet operators and pilots will need to have access to relevant notifications (including NOTAM, Operational Warnings by ATC).

Intra Vertiport Information Exchange

Some level of information exchange, probably using voice communication, will be necessary for coordinating:

- The operations between the ground team and the operation centre.
- The emergency and security situations between the operation centre and the emergency response team (with high priority).
- The operations between the operation centre and the pilot when necessary.

Vertiport to Vertiport Information Exchange

Any coordination information exchanged necessary for safe operation, such as transfer gate, departure information and/or any kind of tactical information.

Vertiport to ATC Facilities Information Exchange

In emergency or contingency operations, it will be necessary to exchange some information between vertiports and nearby ATC facilities.

Flight Operation Data Exchange

Flight plan messages will be dispatched to all Air Traffic Service Units (ATSU) involved in the flight operation.

Vehicle Information

For Horizon 1, it is expected that UAM vehicles will be equipped, at a minimum, with ADS-B In/Out (data), radio VHF (voice). Information provided by the vehicle will be limited to ADS-B Out to provide information including speed, altitude, geolocation, etc. It is expected that UAM vehicles entering service within Horizon 1 will also be equipped with capabilities to support future operations under Horizon 2. Such capabilities may include Controller Pilot Data Link Communications (CPDLC). Data link capabilities on board the aircraft in Horizon 1 may be used to exchange information between vehicle and the network operation centre of the fleet operator and not as a replacement for ATC procedures, which will continue to use traditional voice communication in Horizon 1.

7.2.3 Traffic Management Services to support UAM operations

Traffic management services to support initial commercial UAM operations during Horizon 1 will be composed of existing services (e.g., those provided by ATC) and new/tailored services. Enhanced data can be introduced through future interoperable services such as SWIM (System Wide Information Management) exchanges of data. The SWIM concept has been developed through ICAO and in Europe, EUROCONTROL, for over a decade as part of ATM modernisation as a means to provide a systematic, global approach for digitally managing, accessing and exchanging ATM information. The concept consists of standards, infrastructure and governance for the exchange and management of air traffic information between approved parties and IT systems. SWIM data concepts have been used in the NASA UTM and SESAR U-Space research projects as well as by dozens of UTM software developers to research UTM communications and information exchange. Operational services to support initial commercial operations are categorized under the four unique, but interconnected concepts, introduced in Section 6:

- Flight Planning and Authorization Service
- Flow Management Service
- Dynamic Airspace Management Service
- Conformance Monitoring Service

7.2.3.1 FLIGHT PLANNING AND AUTHORIZATION

During Horizon 1, access to controlled airspace would be through an ATC clearance, as with current aviation operations, particularly helicopter operations. Like all VFR flights, UAM operations would receive traffic information in respect of all other flights and traffic avoidance advice on request. Continuous air-ground voice communications will be required for all flights.

London CTR and London City CTR ATC do not currently make use of flight plans for VFR aircraft. In the London use case, during Horizon 1, clearance would be provided by voice communications with any advanced notice complying with the relevant and current procedures (at the time) to enter controlled airspace. Information for ATC would include:

- Call sign
- Aircraft type
- Requested route
- ETA at the CTR boundary
- Entry point
- Destination
- Requested level

Clearance would be provided using an abbreviated terminology similar to that used for helicopter operations. Depending on whether a tower service was in place at the departure location, ATC clearance may be facilitated by a local tower ATC (as currently happens with the London Helipad at Battersea) or through a phone call from the operator to London or London City CTR ATC.

A key factor of the capacity of UAM over London in Horizon 1 will be the capacity for ATC to provide the applicable level of service provision required for the Class D airspace. It is important to note that, in the London use case, no guarantees of access to controlled airspace could be provided earlier than on departure request. Like any other aircraft, UAM operations in London CTR and London City CTR must expect to not receive a departure clearance for operational reasons such as for capacity of ATC (due to number of aircraft in airspace) or HEMS/Police operations. Similarly, like any other aircraft, UAM operation can still be expected to hold at any point on journey or be required to reroute.

For vertiports with complex or high frequency ground movements and/or complex airspace interaction a level of ATC tower service may be required. The primary function of ATC will be to ensure operational safety at the vertiport. This will be achieved by performing a number of functions, including:

- Vertiport flow management (deconfliction)
- FATO allocation
- Close in airspace monitoring and surveillance
- Stand allocation, in line with schedule and aircraft characteristics

At vertiports which are co-located with a towered aerodrome, it may be more cost effective and feasible to provide a single integrated air traffic service. It will be important to understand how the aerodrome's ATC oversee the vertiport movements and how they are integrated with existing traffic. ATC workload will need to be fully understood if they are necessary to support UAM operations.

Initial implementation of new Flight Planning and Authorisation functions will focus on vertiport FATO availability as initial route and/or corridor structures may not yet be available and initial number of vehicles will be low. In this situation the vertiport resource availability is potentially more significant than airspace capacity, which could be managed by network optimisation and supporting airspace changes. More complex flight planning and authorisation functions, such as 4D trajectories, will be implemented to increase efficiency and airspace capacity utilisation during Horizon 2.

7.2.3.2 FLOW MANAGEMENT

The Flow Management for Horizon 1 will support the limited endurance capabilities of eVTOL aircraft by reserving the departure and arrival slots at the respective vertiports. The Horizon 1 Flow Management will focus on allocating and adjusting time slots at vertiports across the Vertiport network for UAM vehicles. A scheduling system and vertiport availability information management system will need to be developed for each vertiport and integrated across a network of operations. This will be needed to support the regulatory challenges associated with the performance capabilities of eVTOL aircraft to minimize airborne holding due to a FATO being unavailable and provide predetermined alternate landing locations along the route in case deviation from the flight plan is required.

7.2.3.3 DYNAMIC AIRSPACE MANAGEMENT

During Horizon 1, the 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 airspace for use by pilots as assigned by ATC.

7.2.3.4 CONFORMANCE MONITORING SERVICE

During Horizon 1, conformance monitoring will rely on currently available ATM CNS capabilities 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. However, ADS-B does not necessarily scale well with high traffic density, and coverage is possibly insufficient for all phases of flight.

Onboard eVTOL aircraft 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.

Data on route accuracy will be essential to support future safety cases for low-level operations below the currently permitted minimum heights.

It will be necessary to define where and/or under what scenarios additional 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 operation to Horizon 2 (and similarly between Horizon 2 and 3).

7.3 GROUND INFRASTRUCTURE SERVICES

7.3.1 Vertiports

7.3.1.1 SUPPORTING VFR OPERATIONS

Tools and methods to analyse and operationally mitigate the impact of capacity limiting factors already exist in the traditional aviation world and can be applied at vertiports. Once the impact of capacity constraints and other mitigations have been understood, airfield and airspace modelling tools will help define the appropriate location, taxiways, holds, parking stands, etc.

For VFR operations in VMC the required ground infrastructure, markings and signage will be quite basic and will be the same or similar to markings at existing heliports and aerodromes. Markings and other directional arrows may be required to assist pilots during operations. As eVTOL aircraft will be capable of operating into traditional aerodromes it will be important to use standard markings and deviate only when necessary and as the technology evolves.

The effect and impact of weather and severe space weather on the vertiport and the UAM operation will need to be defined and integrated with operational procedures.

For Horizon 1 basic CNS infrastructure is required, including radio communications, and (depending on complexity of the site) lights or ATC control tower or camera that manage the flow of aircraft on the ground and in the first and last stages of flight.

In the first phase of operation, navigation at vertiports could be done in a similar style to airports by using a simple map which is shared with the operators via the AIP or other aviation guides or through some form of data link with the aircraft systems. UK regulatory requirements are expected to include the creation, updating and publication of an airfield map with relevant aeronautical information (windsock locations, taxiways, holds, parking stands, etc). It will be critical that standard markings are used, and deviations are adopted only when necessary.

Local tower ATC, if used, would also be able to verbally communicate navigation at the vertiport via VHF radio. Different forms of surveillance systems may be required to protect operations and allow colleagues on site opportunities to enhance situational awareness to preserve passenger safety.

It is expected that surveillance cameras and other systems will be used that help identify issues related to wildlife hazard management, security, and other operational issues.

More complex vertiports might require ground-based surveillance systems to help monitor the movement of aircraft and other vehicles associated with the operation of the airport. These types of systems could form part of an overall situational awareness and communications system across the vertiport network.

7.3.1.2 VERTIPORT DESIGN STANDARDS

The regulator is expected to publish UK vertiport design standards for new vertiports and potentially for application to existing aerodromes, including heliports, that could also be used as a vertiport prior to or during Horizon 1. eVTOLs are not helicopters or fixed wing aircraft and will require design standards that will support their operations, especially where existing aerodrome facilities are not available, specifically within urban centres.

Design standards in Horizon 1 are likely to be based on existing heliport/aerodrome standards with deviations for eVTOL aircraft, which will be able to perform manoeuvres during take-off and landing that would not be acceptable at heliports using existing rules yet remain consistent with the principles of safety that in the event of power unit failure at a critical point in take-off or landing the aircraft is able to land at position and/or continued safe flight and land.

There are expected to be a wide range of vehicle types and capabilities, which may increase over time with new market entrants or reduce where there is industry consolidation; regardless, vertiport design standards will need to be vehicle agnostic and be able to accommodate the full suite of configurations and capabilities. The regulator may choose to adopt or alight with vertiport design guidance/standards/protype technical specifications already being developed by other aviation regulators. Design standards are expected to feature in any minimum standards required for a licensed vertiport.

7.3.1.3 SIGNIFICANT ADDITIONAL VERTIPORT CONSIDERATIONS

The electrical power requirements and vehicle charging infrastructure will need to be understood and charging points should be standardised where practical to manage vertiports supporting multiple vehicle types. Appropriate ground servicing equipment will be required to support the UAM vehicles. Safe storage requirements for spare batteries and any other hazardous items or substances will need to be developed.

7.3.1.4 VERTIPORTS AT EXISTING AIRPORTS

Airports are complex operating environments with dynamic challenges and changing needs. When locating a vertiport at an airport, there are a number of considerations, including existing aerodrome approaches and runway capacity, safeguarding and other local considerations. Vertiport placement should avoid areas which have an impact on approaching or departing aircraft to ensure safety and protect the throughput of the existing runway operation.

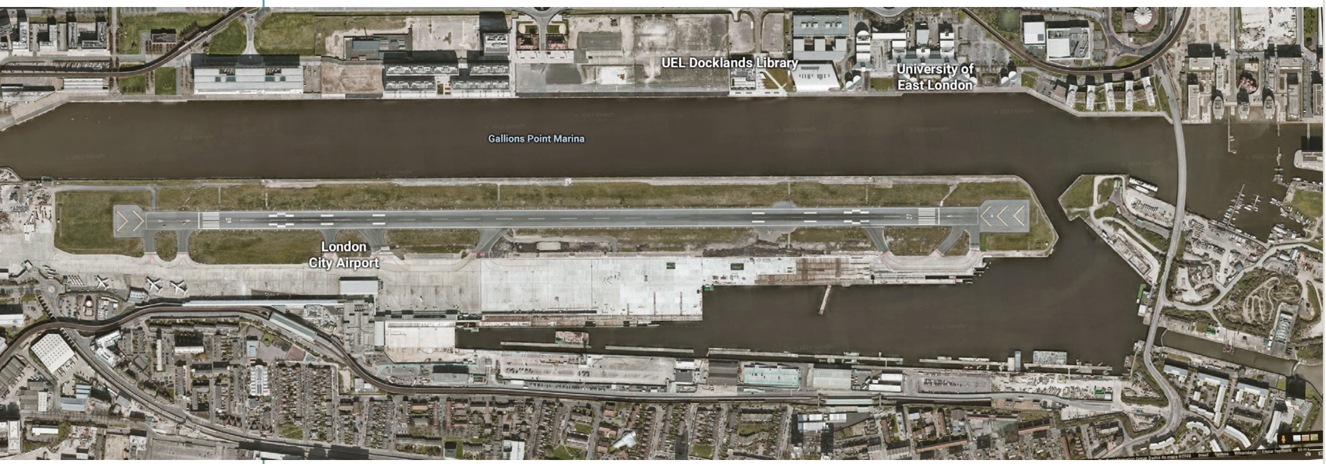
While it is possible to integrate eVTOL aircraft types into the existing aerodrome traffic, at airports with high traffic volumes and limited latent capacity the performance characteristics of eVTOL aircraft mean they would have a negative impact on overall runway capacity. Therefore, where possible it is ideal for UAM operations to be able to occur independently of other operations.

The introduction of aerial activity close to the airport will require Tower ATC to have a clear understanding of the processes and procedures being used at the vertiport, in order to optimise traffic flow. It will be important to ensure operations remain deconflicted at all times in the event of baulked landings or when traffic needs to 'go around'.

The placement of any vertiport must also consider its impact on safeguarded elements to ensure safety and understand its impact on operations and the neighbouring communities. Airports are often located in areas where consideration should be given to local sensitive receptors.

LOCATING A VERTIPORT -
» Case study London City Airport

London LCY is located approximately 8 miles to the East of central London. It is located adjacent to the financial district, river Thames and Excel exhibition centre. The airspace around the site is also complex, with the airfield having a steep approach to avoid obstacles. Other airport/airspace interactions including helicopter routes to the south and London terminal manoeuvring area above. The site has a single runway in an east west configuration. The runway operation is mixed mode (landing and take-off coordinated on the same runway), and the operation is predominantly into westerly winds with arrivals from the east.

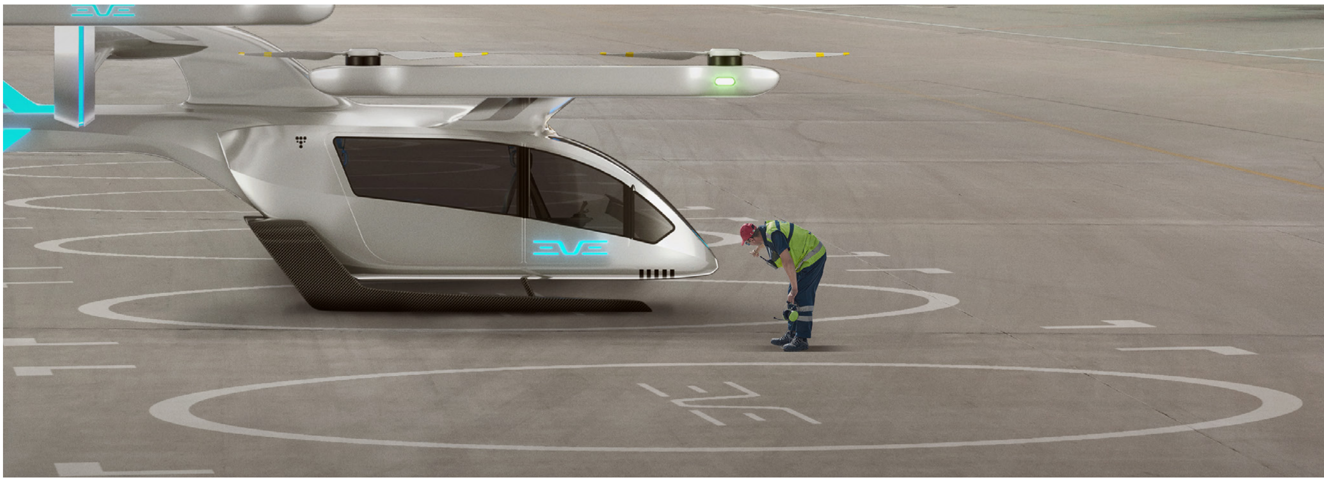


An airport of this complexity will already have a number of safeguarding procedures to protect the operation. These will include physical safeguards around the runway (i.e., OLS), safeguarding for navigational equipment including runway landing aids (i.e., Instrument Landing Systems), surveillance equipment and line of sight from control towers, cameras, or remote VCR now in operation.

In terms of sensitive receptors, London City may have specific noise abatement procedures to protect local residences including schools, nurseries and hospitals.

London City Tower ATC will need to have a clear understanding of the processes and procedures being used at the Vertiport. As a minimum controllers would want to know what the operating procedures are and they don't interfere with the existing operation of the airport. However, for more complex operations ATC may need to become involved with the operation of the vertiport. For example, vehicles wishing to fly north of the existing site may be given a route over the top of the airfield if appropriate procedures can be designed. This would require ATC to provide positive deconfliction, including coordinating with the aircrews involved.

7.3.2 Integration with existing ground infrastructure



The complexities of integrating vertiports and UAM operations within an aerodrome will vary depending on the physical size of the airport, including the apron area that the vehicles will use and their proximity to other aerodrome users, as well as existing traffic levels. Smaller airports are likely to prefer vertiports to be sited away from the airfield environment to deconflict with existing operations but remain within the airport footprint and close enough to terminal buildings to provide interchangeability with the other air services and to make use of existing surface access infrastructure. Larger airports may site vertiports within the airfield but in demarcated areas to deconflict ground traffic and to avoid security screening for passengers required when entering the Critical Part or airside environment.

The following areas will need consideration when planning a vertiport on or close to an airport:

- The vertiport should make use of existing airport's rail, underground and road networks to avoid introducing new surface access challenges and provide accessibility for all.
- Interchangeability between UAM services and existing air and ground services should be as frictionless and quick as possible for the passengers.
- Dedicated facilities and access may be required for a vertiport that is not connecting passengers from other air services and operating just point-to-point services across the city.
- Airport Emergency services may require specialist equipment and a change to their training to include the hazards from electric vehicles and specifically large battery fires[8].
- Specific safety training for airport ground staff to understand the hazards, particularly when eVTOLs operate within the airfield apron and adjacent to fixed wing aircraft.
- Safeguarding of the vertiport and impact on the airports safeguarded surfaces (OLS) will need to be ensured.
- Environment impact and noise profile of the vehicles and components and the pre-requi-site management systems that will be necessary to monitor performance.
- Availability of ATC where vertiports are co-located with airports in controlled airspace.

[8]Research by the UAM industry and the regulator into the hazards and mitigations for battery fires, and the impacts fires will have on emergency services, will need to continue throughout Horizon 0 and 1.

SECTION 8

CONCEPT OF OPERATIONS: HORIZON 2

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8.3 Ground Infrastructure Services 78

BACK TO MENU

HORIZON 2 IS WHEN THE SUSTAINABLE BUSINESS CASE FOR UAM EMERGES AND IS AN ESSENTIAL STEP TOWARDS SUPPORTING FUTURE AUTONOMOUS OPERATIONS INTRODUCED IN HORIZON 3 WHERE THE UAM BUSINESS CASE MAY BE FULLY REALIZED.

As described in Section 5, Horizon 2 will introduce new ATM procedures and technologies to support UAM operations beyond what the current environment can accommodate. The new services introduced in Horizon 2 will therefore mature at different rates. This will include a transition period from Horizon 1 where initial capabilities are introduced to mature services that will be needed to support autonomous operations introduced in Horizon 3.

The conditions necessary to exit Horizon 2 and enter into Horizon 3 where there will be a high-density UAM operations with piloted and autonomous UAM vehicles supported by UAM traffic management services is being explored by other bodies of work and is outside the scope of this CONOPS.

This chapter focuses on the challenges and broad concepts that are likely to be applicable in Horizon 2.

8.1 REGULATORY CHALLENGES

In this the section the considerations for Horizon 2 regarding the regulatory challenges introduced in Section 4.2 are described. New regulatory challenges will emerge in Horizon 2 while some of the challenges addressed in Horizon 1 will evolve and become more complex.

8.1.1 Scaled UAM Operations

8.1.1.1 HUMAN PERFORMANCE COMPLEXITIES IN NETWORK MANAGEMENT

With an increase in density and tempo of UAM operation in Horizon 2, the complexity of network management will increase as well. An increased number of UAM fleet operators, vertiport operators and types of aircraft with varying operating performances will further increase the complexity of network management.

The dynamic nature of operations planning, and the percentage of on-demand operations may increase in Horizon 2. Additionally, the range of destinations and routes are also expected to increase as more vertiports locations are introduced.

The ability for humans, including ATC and pilots, to safely deconflict aircraft will reduce as traffic complexity increases. The effectiveness of existing ATM and CNS solutions to manage this complexity will also degrade. New approaches to airspace design, information management and traffic management will be required to support the increased network complexity in Horizon 2.

8.1.1.2 FAIR AND EQUITABLE ACCESS TO AIRSPACE

In Horizon 2 there will be an increased number of UAM operators with a variety of operations seeking access to the same airspace. These new operators will need to integrate with existing airspace users (e.g., helicopters, general aviation) as well as an increasing number of other emerging airspace users including RPAS.

UAM operations will need to integrate with new airspace access rules and systems which enable fairness and equity as well as other airspace performance characteristics. New approaches to airspace design to support Horizon 2, along with the information management and traffic management solutions derived to support the new procedures, will need to consider how it supports the fair and equitable access to airspace for all airspace users.

8.1.2 LOW-LEVEL FLYING IN CONGESTED AIRSPACE

8.1.2.1 ENABLING VISUAL AND INSTRUMENT METEOROLOGICAL CONDITIONS (VMC & IMC) OPERATIONS

UAM only operating under VFR and VMC may work for initial operations but will quickly limit predictability and service availability. However, as the density of operations increase, current VFR procedures will not be adequate and limit capacity.

Additionally, UAM operations will also need to fly under IMC to achieve the sustainable business case of Horizon 2. Current rules prevent low-level flights under IMC.

Given the limitation of IFR flights operating below about 2,000ft, neither IFR nor VFR provide a complete framework under required operational meteorological conditions to support regular UAM operations in Horizon 2. New regulations to enabling IMC operations for UAM aircraft with provision for low-level flying will be required.

It is expected that the existing flight rule set will evolve, in isolation for eVTOL or as a hybrid for all suitably equipped aircraft, to realize the safety and operational benefits which are brought about by new technology and aircraft performance capabilities, allowing operations not only at lower altitudes or areas where traditionally, similar flights may have been excluded, but also in all-weather scenarios and at all times of the day, thus ensuring the system is capable of meeting the volume and tempo predicted in user business cases.

8.1.2.2 SOCIAL LICENSE

The social license developed in Horizon 1 will need to be maintained and strengthened during the growth of operations in Horizon 2.

In Horizon 2, the number of vertiport locations will increase as well as the number of operations. The community will be more familiar with UAM operations by Horizon 2, including the associated scale and impact of aircraft noise and visual pollution. The impact of increased operations will need to be managed to ensure continued community support, as growth will only occur with this support.

This can be potentially achieved, in part, through dynamic management of airspace and/or defined routes to share aircraft noise and prevent overflight concentration over one community and through access to community-sought information such as noise/performance of operations.

The safety considerations associated with increased number of operations, operations in IMC and increase level of low flying will need to be included as part of the social license.

8.1.2.3 FLIGHT IN CLOSE PROXIMITY TO OTHER LOW-FLYING TRAFFIC AND WITHIN THE OBSTACLE ENVIRONMENT

In Horizon 2, a modernized airspace design will allow UAM aircraft to operate in a shared and integrated ‘single sky’ airspace environment across the UK, allowing local communities to reap benefits of UAM in urban areas. The high-volume and dynamic nature of UAM operations will increase the cadence of close-proximity flights with other low flying traffic (such as helicopters and UAS operations) and frequency of flights in close proximity with obstacles.

It is expected that aircraft such as UAM and RPAS would have increased levels of automation by Horizon 2, to allow a certain extent of ‘detect-and-avoid’, which would provide assurance for shorter separation distances and thereby support higher volume of UAM operations.

8.2 SUPPORTING FUTURE COMMERCIAL OPERATIONS THROUGH NEW FRAMEWORKS AND SYSTEMS

This section describes the planning, design and operational considerations for Horizon 2. It uses the conceptual framework defined in Section 6 as a structure to address key areas relating to traffic management and vertiport planning. Further consideration of ground operations is provided in the next section.

8.2.1 Airspace and Procedures Design

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

The following areas will be of key consideration in Airspace and Procedures Design for Horizon 2:

- Airspace structures
- Vertiport location planning
- Vertiport licencing
- Airspace Change Process

8.2.1.1 AIRSPACE STRUCTURES

There are several airspace structure concepts under development for mature UAM operations being explored around the world. This CONOPS provides an overview of some of these concepts in respect to the regulatory challenges identified.

U-Space

The European Union has developed regulations for UAS called U-Space: the phased introduction of procedures and "a set of services designed to support safe, efficient and secure access to airspace for large numbers of drones" to encourage the growth of the UAS industry and the use of these aircraft in Europe. These services and procedures rely on a high level of digitisation and automation of functions, whether they are on board the drone itself, or are part of the ground-based environment. However, U-Space regulations do not currently apply to piloted UAM operations and only cover UAS at very low levels, likely below the levels that UAM will operate. Furthermore, with the competing and contrasting demands for use of the future airspace there is likely a need for an Airspace Manager role to oversee the management of the airspace from the perspectives of safety, security, capacity and fair use. The U-Space regulations do not provide the Airspace Manager role thus limiting the potential usefulness of a U-Space airspace structure as demand and traffic mix of UAM and UAS increases.

SESAR Concept of Operations for European UTM Systems (CORUS)

Under SESAR2020 exploratory research programme, the SESAR Joint Undertaking has sponsored a CORUS project to write low-level CONOPS for U-Space. The CORUS project proposed that the airspace may be divided into different parts according to the services provided. These basic configuration types are:

- X: No conflict resolution service is offered
- Y: Only pre-flight conflict resolution is offered
- Z: Pre-flight conflict resolution and in-flight separation are offered

UAM Operating Environment[10]

The NASA UAM Concept of Operations introduces the UAM Operating Environment (UOE) where UAM vehicles will predominantly operate. Per the NASA UAM Concept of Operations, the UOE is a flexible airspace area encompassing the areas of high UAM flight activity. The maximum possible extent of the UOE is static and can be represented on traditional aeronautical charts. Within this maximum area, there are flexible areas that are "available" and can change. For example, if the flow pattern at a nearby major airport changes, the available UOE may change to avoid potential traffic conflicts among UAM aircraft and traditional commercial airlines.

Within the UOE are high-density routes and vertiports supporting high-demand UAM operations. The UOE may more easily enable the introduction of new vertiport locations and routes while following the necessary community engagement process.

UAM vehicles operating within the UOE would be provided the UAM traffic Management services necessary to support the density and complexity of the operations. Other aircraft, including but not limited to helicopters, GA aircraft, and small RPAS can fly in the UOE if they are able to safely participate in the management and separation of traffic within the UOE through connection with the UAM traffic management services provided within the UOE.

UAM vehicles can fly both inside and outside of the UOE, but aircraft flying outside the UOE will follow the requirements of the airspace they operate within, including satisfying equipage requirements.

The UOE presents a potential solution for mature Horizon 2 operations and is unlikely suited to support initial operations beyond what can be supported by Horizon 1.

[10] https://ntrs.nasa.gov/api/citations/20205011091/downloads/UAM%20Vision%20Concept%20of%20Operations%20UML-4%20v1.0.pdf

UAM Routes

UAM Routes are proposed airspace constructs specifically designed for the connection between vertiports in the urban air mobility context. They are similar to Helicopter Routes and provide connections routes between vertiport entry and exit points. UAM Routes can organize operations between vertiports (and airports) through defined flight paths, safely navigating on congested and build-up urban areas. Their implementation does not depend on new regulations or procedures as it is compatible with current helicopter route procedures, based on assumptions that the regulations and rule sets supporting the helicopter routes are also applicable to the UAM route structure.

UAM Routes are non-exclusive airspace and can be crossed by other airspace users, including providing connections to existing helicopter routes. A set of routes in an urban environment will form a network of routes with multiple points of interconnection between routes and to vertiports/airports.

Route advantages are simplified early adoption based on the existing regulation framework and coexistence with current low-level airspace routes and users. As traffic volume between vertiports increases, a non-exclusive route using existing regulations will become a limiting factor in volume of operations and a source of capacity variations and operational uncertainties.

UAM Corridors

The UAM corridor concept has been proposed by NASA, the FAA, EUROCONTROL and other aviation authorities as a dedicated airspace corridor connecting vertiports. It can be defined as a performance-based airspace of defined dimensions in which aircraft abide by UAM specific rules, procedures, and performance requirements. A dedicated airspace for UAM operations may be desired when specific performance requirements, precise navigation, 4D flight operations become essential to support higher volume and density of flights, particularly around airports within controlled airspace

The UAM corridor implements airspace reservation around one or more routes, proposes a means for strategic and tactical separation of flights in higher density conditions. In this scenario, aircraft must be equipped with UAM compatible systems and follow specific procedures to operate inside a corridor.

However, there are challenges to the implementation of UAM corridors, particularly while gaining social licence as they reduce access and equity of other airspace users. It may therefore be practical to only use corridors for UAM operations in certain, limited situations (i.e., integration around airports).

Free route airspace

Free Route Airspace (FRA) provides airspace users with the ability to flight plan and fly the most efficient route of their choice without being constrained by the ATS route network; this allows airspace users to realise efficiencies in their day-to-day operations.

In FRA, airspace users may freely plan a route between a defined entry point and a defined exit point, with the possibility to route via intermediate published or unpublished way points, with or without reference to the ATS route network, subject to airspace availability. The design and implementation of FRA will ensure connectivity with adjacent non-FRA airspace, allowing airspace users to flight plan seamlessly between any two airspace volumes, which may include other forms of airspace structure described in this section.

FRA is to be progressively introduced, wherever operationally practicable and beneficial, in order to optimise flight planning opportunities for airspace users, presenting a potential holistic solution for mature Horizon 2 operations.

8.2.1.2 VERTIPORT LOCATION PLANNING

Vertiport design, as well as VTOL operational, requirements, largely determined by VTOL airworthiness criteria, will substantially influence the location of vertiports, particularly in congested environments. Based upon experience gained during Horizon 1, vertiport design requirements will need to be provided to enable the development of a network of origin and destination vertiports, which can also act as alternates for continued safe flight and landing (CSFL) of category 'enhanced' VTOL or equivalent for use in congested environments.

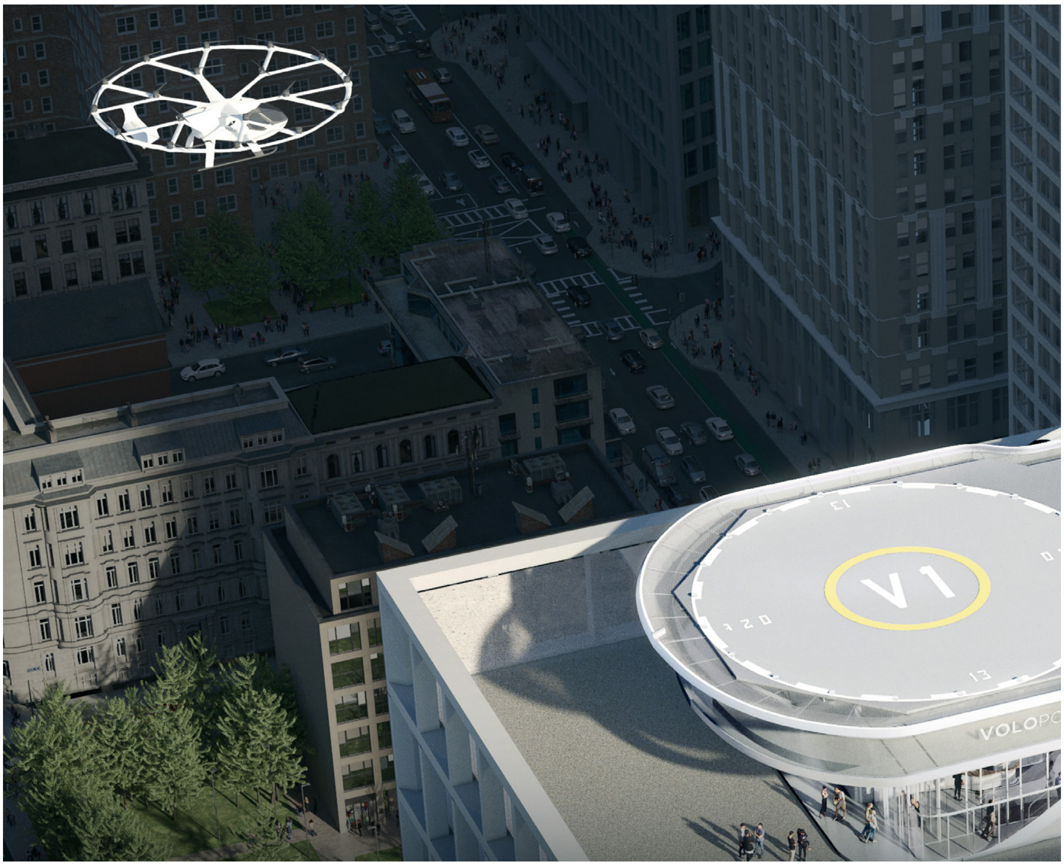
CAP168 provides design requirements for aerodromes and heliports that are subject to licencing and provide a foundation on which to build specific vertiport design requirements. However, aerodrome and heliport design requirements, based on existing ICAO Annexes for aerodrome and heliports, are not completely fit for purpose for VTOL capability and would render viable vertiport sites as unsuitable without significant adaptation due to existing excessive sizing requirements and approach/departure surfaces designed for helicopters.

8.2.1.3 VERTIPORT LICENSING

A vertiport licensing regime is expected as a requirement to enable scheduled commercial flights and/or public transport flights. CAP168 Licensing of Aerodromes provides a foundation on which to develop licensing rules for vertiports but is insufficient to enable safe scheduled commercial flights and/or public transport for UAM flights. Requirements for battery fire suppression and associated RFFS, and the role of supporting traffic management technologies and services, for instance, are not included and will be a vital consideration for the siting and safe operation of a vertiport for electric VTOL.

Progress on a licensing regime is expected to require progress having been made on the development of vertiport design requirements; indeed, vertiport design standards are a more urgent requirement for all vertiports to be designed and developed.

Efforts by international standards organisations (SDOs) to develop guidance for vertiport operators and operations provide a useful foundation on which to build a vertiport licensing regime.



8.2.1.4 AIRSPACE POLICY

One of the regulatory challenges for UAM operations is related to airspace policy. As mentioned in section 4.3, the current airspace and airspace classification system would need to be adapted in Horizon 2, for the progress of UAM operations over an extended period of time in a low airspace environment such as London.

Moreover, interlinked to the airspace policy, the Airspace Change Process (ACP) described within CAP1616 serves as a current mechanism to establish the initial operation of UAM within UK airspace, but it does not facilitate the "build on" scenario that is envisaged for the growth of UAM in Horizon 2 when vertiports are expected to be introduced more dynamically. CAP1616 is designed to provide guidance for a single airspace change. If subsequent changes are required for a further piece of airspace or additional areas are to be over flown, a new ACP would be required to commence, and the full process would need to be followed. Without adjustments to the ACP, future adaptions of the airspace would require a full airspace change.

This CONOPS explores protentional approaches for consideration to Airspace Change Process solutions for UAM. Three potential approaches were considered by assessing the positive, neutral, or negative impacts in respect the CAA acceptance, cost, time, and stakeholder acceptance.

The first protentional approach is to apply existing CAP1616 process to UAM, in line with existing CAA processes, although the process is costly and most time-consuming as several airspace changes are expected for the "build on" UAM scenario in Horizon 2. Furthermore, the extended time and multiple repetitions of stakeholder consultation could diminish focus to the requested airspace changes over time, making the stakeholder engagement and acceptance hard to achieve.

The second protentional approach is to create a bespoke UAM Airspace Change Process, outside the existing framework of CAP1616 process. This could provide a fast-track approach for UAM operators, but the separate treatment could invite backlash from other airspace users, making stakeholder acceptance unlikely.

The third protentional approach is to adapt the airspace change process, with specific tailoring to new airspace users, including UAM. UAM will hence form a subset of airspace users to be considered under the airspace policy, which should be closely aligned with the Airspace Modernisation Strategy. This approach seeks to balance the different operational demands of new aircraft types and flight efficiency of the whole aviation ecosystem.

Application of CAP1616 for UAM

Following the potential approaches proposed above, there are elements of CAP1616 that be utilized for UAM. This CONOPS provides three examples where elements of CAP1616 can be applied.

CAP1616 emphasizes the importance of engagement with stakeholders, covering a variety of activities, which will continue to be necessary for UAM. Consultation, or a formal, notified period seeking input from stakeholders (with an interest in changes that impact airspace) on proposals, is one element of engagement within the process, but engagement can also include information provision, regular and one-off meetings and fora, workshops, and 'town hall' discussions and other contact with third parties.

Clear demarcation of responsibilities between the change sponsor and CAA is expected to continue for UAM. The responsibility for engaging with and informing communities about specific airspace change proposals rests with the change sponsor. The CAA only engages with stakeholders at defined points in the process, in a fair and transparent way.

Legal requirements for airspace changes to holistically consider safety, environment and needs of airspace users will continue to be necessary to support the growth of UAM. Set out in section 70 of the Transport Act 2000, there is a range of legal requirements that must be met before the CAA agrees on any airspace changes. These factors include safety, security, operational and environmental impacts, such as aircraft noise and emissions.

Suggested Improvements to CAP1616 for UAM

Per the challenges previously captured, this CONOPS presents suggested areas that an adapted airspace change process would need to consider accommodating the growth of UAM.

Due to dynamic and frequent introduction of new vertiport locations and defined routes, a shortened process for changes in airspace design may need to be considered. A quickened process to assess the potential impact on redistributed air traffic around vertiports, as well as the changes to air traffic control operational procedures will require CAA approval.

Additionally, this will also likely require streamlining the expanded engagement process. Every vertiport and additional route will need to seek inputs from stakeholders (with an interest in changes that impact airspace). The multiple vertiports in the vicinity of local communities and businesses could trigger several simultaneous consultations, thus a streamlined approach is necessary to avoid consultation fatigue, while balancing the need to holistically consider the needs of other airspace users.

8.2.2 Information Exchange

The objective of the Information Exchange Service in Horizon 2 is to ensure a level of situation awareness for all UAM stakeholders commensurate to their safety accountabilities in the airspace, with timely and accurate data exchange from the ANSP and industry systems. As a result, the Information Exchange Service will enable UAM traffic management services to support safe and efficient operations.

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.

The exchange of information with all key stakeholders, including vertiport operators, fleet operators, the booking platform, vehicle operators, the ANSP and RPAS operators and service suppliers will commence in Horizon 2. Reliance on voice-based communication is expected to decrease in Horizon 2, but capability is likely to have to be maintained in some airspace. 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 be necessary to enable the introduction of autonomous UAM vehicles.

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 optimized for dense UAM environments considering projected traffic density, high operational tempo, frequency of position adjustments and more granular operations.
- Current ATM CNS technologies are likely to have insufficient coverage and capacity for high-density UAM operations.
- ADS-B frequency saturation may become an issue as more aircraft are entering operations.
- Certain types of information that is pertinent to UAM operations but not relevant to other aircraft operations are not supported by current ATM information management systems. An example of this is vertiport infrastructure resource usage.

8.2.3 Traffic Management Services to support UAM operations

Traffic management services to support initial commercial UAM operations during Horizon 2 will be composed of primarily new/tailored services with increased levels of automation and reduced reliance on voice-based communication.

Key functions explored in other bodies of work to support operations that may provide concepts applicable to enabling UAM in the UK include:

- Provider of Services for UAM
- Supplemental Data Service Providers
- Vertiport Automation System Services
- Integrated Traffic Management
- UAS Traffic Management Integration

The SWIM exchange of data, four operational services introduced in Section 6 and applied in Horizon 1 to support initial commercial operations will continue to evolve and mature to support increased density, tempo, and complexity of operation in Horizon 2. These four operational services are[11]:

- Flight Planning and Authorization Services
- Flow Management Service
- Dynamic Airspace Management Service
- Conformance Monitoring Service

8.2.3.1 FUNCTIONS SUPPORTING UAM TRAFFIC MANAGEMENT SERVICES

Provider of Services for UAM[12]

Per the regulatory challenge Human Performance Complexities in Network Management, it is expected that UAM operations in Horizon 2 will exceed the capacity of existing, human-operated ATC systems. A Provider of Services for UAM (PSU) is introduced in the NASA UAM Concept of Operations as an industry alternative to provide ATM services for UAM operations under the rules and regulations established by the regulator.

The NASA UAM Concept of Operations proposes UAM traffic management services be provided by a network of approved PSUs from industry that coordinate responsibilities through a PSU network. However, other options to provide UAM traffic management services may also include a single PSU delegated by the ANSP, or by the ANSP themselves. The possibilities of airspace management will highly depend on the types of airspace to be optimized as well as the UK regulatory environment.

Supplemental Data Service Providers

New traffic management services to support Horizon 2 (e.g., provided by PSUs) will require a range of data from various approved sources to enable UAM operations. Supplemental Data Service Providers (SDSPs) may be used by a PSU(s) or ANSP to access supporting data including, but not limited to, terrain, obstacle, aerodrome availability, and specialized (e.g., localized) weather information.

SDSPs may be accessed by those providing UAM traffic management services to support operational services such as Flight Planning and Authorization and Flow Management as well as directly by the UAM fleet operators and vertiport operators. Access to relevant information through SDSPs may also support the regulatory challenges Fair and Equitable Access to Airspace and Social License through the fair and transparent access to UAM related information.

[11] Much of the content used to describe the four operational services for Horizon 2 is from the Urban Air Traffic Management Concept of Operations: https://daflwcl3bnxyt.cloudfront.net/m/3dc1907d3388ff52/original/PPJ016561-UATM-Concept-of-Operations-Design_D11-FINAL.pdf
[12] https://nari.arc.nasa.gov/sites/default/files/attachments/UAM_ConOps_v1.0.pdf
https://ntrs.nasa.gov/api/citations/20205011091/downloads/UAM%20Vision%20Concept%20of%20Operations%20UML-4%20v1.0.pdf

Vertiport Automation System Services[13]

Horizon 2 will see an increase in vertiport locations with varying sizes and configurations. A Vertiport Automation System (VAS), introduced in a concept of operations authored by NUAIR and published by NASA, focuses on providing services to support high-density vertiport locations with high-throughput operation capabilities.

Per the CONOPS, the VAS is responsible for the scheduling and sequencing of vertiport resources and coordinating with external stakeholders to support high-density operations. Due to the network complexity in Horizon 2 and the increased levels of integration required to support operations, vertiports with lower-density operations may also require VAS services.

VAS services may be provided as an extension to those providing UAM traffic management services (e.g., a PSU), a SDSP, or by the vertiport operator themselves.

Integrated or Unified Traffic Management

Increased levels of integration across all airspace users and service providers are expected to be necessary to support operations with greater density and complexity. An Integrated or Unified Traffic Management approach proposes a single framework that enables all operators to share the airspace harmoniously. This approach is expected to develop iteratively overtime and may be necessary to support a mature Horizon 2 and Horizon 3 when autonomous operations are introduced.

Due to the complexity of integrating and scaling UAM operations, the solutions to this challenge may serve as a blueprint for a Unified Traffic Management framework to support the full integration of existing and other future airspace users.

UAS Traffic Management Integration

UAS Traffic Management is currently composed of the systems and services used to support small UAS (e.g., below 55lbs) operations in uncontrolled airspace at low-levels (e.g., below 400’ AGL). Integration with UAS Traffic Management is expected to be necessary to exchange information about small flying in the vicinity of UAM operations including those around vertiports to support situation awareness.

Due to the unique nature of small UAS operations, it is not expected that UAS Traffic Management as described today, will be capable of providing services necessary to support UAM operations due to the differences is safety, ground infrastructure constraints, and levels of integration necessary with other airspace users. However, concepts being developed in UAS Traffic Management systems to support beyond visual line of sight (BVLOS) operations, such as 4D flight trajectories, will likely be applicable to the traffic management services necessary to support UAM in Horizon 2.

[13]https://ntrs.nasa.gov/api/citations/20210016168/downloads/20210016168_MJohnson_VertiportAtmtnConOpsRprt_final_corrected.pdf

8.2.3.2 FLIGHT PLANNING AND AUTHORIZATION

The objective of the Flight Planning and Authorization Service is to develop and maintain a plan and issue an authorization in response to a flight request for a UAM vehicle movement. The flight plan and authorization must align with the strategic objectives of the overarching UAM system.

During Horizon 2, a new form of UAM airspace (e.g., UAM Operating Environment) could remove the need for clearance by ATC to access controlled airspace. ATC clearance will still be required in certain circumstances, including when operating in controlled airspace outside of designated UAM airspace and during off-nominal scenarios.

CHALLENGES WITH CURRENT OPERATIONAL CAPABILITY

The following challenges to implementing the Flight Planning and Authorization Service with current operational capability have been identified.

- Due to the low-density of helicopter operations in low-level airspace and their ability to hover for prolonged periods of time in comparison to eVTOLs, 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, limiting any ability to coordinate traffic with helipad bookings.
- Current authorization procedures cannot guarantee access to controlled airspace prior to departure.

8.2.3.3 FLOW MANAGEMENT

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 limited resources in the airspace a vertiports. In Horizon 2, the Flow Management Service will rely on high levels of automation to accommodate increased demand of UAM operations and minimize additional burden on ATC.

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 interactions.

8.2.3.4 DYNAMIC AIRSPACE MANAGEMENT

The objective of the Dynamic Airspace Management Service is to maximize the performance of low-level airspace and its structure as environmental and operational needs shift. The service also aims to be response to ATM needs during nominal and off-nominal scenarios. In Horizon 1, dynamic management of the airspace is expected to be conducted by the controllers where in Horizon 2 this service will need to be largely automated and integrated with the other services.

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 clearance to operate in certain areas).
- ATM does not currently have the capability to define dynamic airspace structure for UAM vehicles in the low-level airspace.

8.2.3.5 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 response for impacted UAM vehicles. This data will also support he systemic review and analysis of UAM operational performance. Similar to the Dynamic Airspace Management Service, the Conformance Monitoring Services was primarily carried out by ATC in Horizon 1 and will require higher levels of automation and integration with the other services to support Horizon 2.

CHALLENGES WITH CURRENT OPERATIONAL CAPABILITY

The following challenges to implementing the Conformance Monitoring Service with current operational capability have been identified:

- 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.

8.3 GROUND INFRASTRUCTURE SERVICES

8.3.1 Vertiports

The purpose of vertiports is to provide a location from which air taxi operations will take place. New, dedicated vertiport facilities will be required to enable routing where existing aerodromes, including heliports, do not already exist or cannot be used. Existing aerodromes, airports and/or heliports may be suitable locations from which to operate air taxis, subject to licencing requirements for scheduled commercial transport and/or public transport flights. It is likely that even existing aerodromes, airports or heliports will require development of dedicated eVTOL landing infrastructure and supporting facilities such as re-charging equipment.

8.3.1.1 VERTIPORT DESIGN STANDARDS

The objective of dedicated vertiport design guidance or regulations is to provide a means for vertiports to be designed and built to standards accepted by the competent authority and that enable eVTOL to execute manoeuvres for which they have been designed. In Horizon 1, vertiport design standards should in the first instance be based on existing heliport and aerodrome design standards. In Horizon 2, the design standards should be iterated where necessary to reduce unnecessary physical requirements and optimise the operating requirements using OEM performance data.

CURRENT CHALLENGES

The following challenges to developing performance-based vertiport design standards have been identified:

- Lack of sufficient performance data to be shared with the competent authority.
- Lack of UK type certification and continued airworthiness approval regime for eVTOL.
- Insufficient progress being made on interim vertiport design guidelines for VFR operations using existing heliport and aerodrome rules as a foundation.
- Lack of clarity how existing airport assets can safely accommodate eVTOL operations.
- Lack of ICAO SARPs for vertiport design.

GENERAL DESCRIPTION FOR HORIZON 2

Early in Horizon 2, interim vertiport design guidance or regulations will enable the development of dedicated vertiport facilities, as well as support operational planning by enabling eVTOL continued safe flight and land with the provision of sufficient en-route alternates. Interim design guidance should also inform changes to national and local planning guidance which should recognise the concept of vertiports and enable planning consent being given for new facilities and changes to existing airports/heliports with a vertiport where planning approval is required. Interim guidance will have been developed for initial VFR operations initial, but as Horizon 2 advances performance-based designs standards will be able to accommodate IFR operations.

8.3.1.2 VERTIPORTS AT EXISTING AIRPORTS

The objective of locating vertiports at existing airports is to maximise:

i) the use of existing airport facilities.

ii) provide seamless connectivity between air taxis services and commercial air transport services, for which the former can provide onward transport into cities and elsewhere and vice versa into the airport; acting as surface transport alternatives and complements.

CURRENT CHALLENGES

The following challenges to do developing vertiports at existing airports have been identified:

- Lack of planning guidance on vertiport infrastructure to local planning authorities to approve an application by an airport.
- Locating a vertiport airside for air taxi services making an onward journey to the final destination without the passenger first passing through immigration and security.
- Operational procedures would be required to seamlessly and safely integrate vertiport operations into the movement area.
- The inclusion of a vertiport within the movement area at an existing licensed aerodrome may not be acceptable under the terms of the licence.
- Airports that are economically regulated may not be permitted to recover the costs of investment in vertiport infrastructure through landing charges.
- Existing airports may not be permitted for use as en-route alternates for CSFL.

GENERAL DESCRIPTION FOR HORIZON 2

Early in Horizon 2, the vertiport concept is expected to be incorporated in national planning guidance to enable local planning authorities to approve new vertiports and vertiports at existing airports. A vertiport licensing regime should complement the existing aerodrome licensing regime, and could be used to enable vertiports to be incorporated into the movement area at existing airports. Initial operational procedures developed during Horizon 1 will be further developed to accommodate increasing demand and the number of air taxi movements at the airport.

SECTION 9
ACRONYMS AND GLOSSARY

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9.1 ACRONYMS

AC	Advisory Circular
ACP	Airspace Change Process
ADS-B	Automatic Dependent Surveillance-Broadcast
AGL	Above Ground Level
AMS	Airspace Modernisation Strategy
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Service
ATSU	Air Traffic Service Units
BVLOS	Beyond Visual Line of Sight
CFIT	Controlled Flight Into Terrain
CNS	Communication Navigation Surveillance
CPDLC	Controller Pilot Data Link Communications
CRM	Collision Risk Modelling
CSFL	Continued Safe Flight and Landing
CTR	Control Zone
eVTOL	Electric Vertical Take-Off and Landing
FATO	Final Approach and Take-Off Area
FRA	Free Route Airspace
GA	General Aviation
ICAO	Internation Civil Aviation Organization
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
LOC-I	Loss of Control In Flight
NOTAM	Notice to Airmen
OLS	Obstacle Limitation Surfaces
PBN	Performance Based Navigation
PSU	Provider of Services for UAM
RA(T)	Restricted Area
RP	Reporting Point
RPAS	Remotely Piloted Aircraft Systems
SDSP	Supplemental Data Service Provider
SERA	Single European Rules of the Air
SVFR	Special VFR
TDA	Temporary Danger Area
TLOF	Touchdown and Lift-Off Area
TMZ	Transponder Mandatory Zone
TRA	Terminal Reserved Area
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System
UOE	UAM Operating Environment
UTM	UAS Traffic Management
VAS	Vertiport Automation System
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VRP	Visual Reference Point

9.2 GLOSSARY OF ICAO KEY PERFORMANCE AREAS

Source: ICAO (2005). Global Air Traffic Management Operational Concept (Doc 9854)

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 mee 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 toa 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 deferent 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 efficient, flexibility, and predictability while ensuring that there are no adverse impacts to safety giving due to 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 element 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.

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