UK
Civil Aviation
Authority

Innovation Hub

Key Considerations for Airspace Integration within an Urban Air Mobility Landscape

Future Air Mobility Sandbox

The Eve Sandbox Case Study

The UK Civil Aviation Authority's (CAA) Regulatory Sandbox helps industry innovators to increase their chances of complying with future regulations.

This is achieved by ensuring development activities identify the key challenges that innovation can bring in terms of safety, security and consumer protection. By working with innovators via the Regulatory Sandbox, the CAA aims to tackle challenges at an early stage, helping to accelerate the pathway to approving novel technologies and concepts.

Following the launch of our Future Air Mobility Regulatory Sandbox, a consortium led by Eve Urban Air Mobility Solutions came together to consider the UK case. The consortium, working together with the CAA Innovation Hub, are developing a concept of operations for Urban Air Mobility (UAM) operations, focusing on the transportation of passengers over London in novel vertical take-off and landing (VTOL) vehicles.

Within this publication **we share the key considerations for integrating UAM operations into UK airspace from the perspective of the Eve case study.**

The work being done within the Sandbox is still evolving, but by sharing work as it progresses we hope to support innovators wishing to influence and implement airspace design, procedures and infrastructures for safely integrating UAM operations into low-level airspace.

The CAA Innovation Hub welcomes feedback on these key considerations to help us to identify other areas to explore and continue our iterative learning process.

Eve Sandbox Case Study

Transporting passengers over London in novel electric and hybrid VTOL vehicles

EVE

MOBILITY REIMAGINED

Who are the Consortium?

In addition to Eve, the consortium includes international companies that span the aviation industry, including:

- Heathrow Airport;
- London City Airport;
- NATS;
- Skyports;
- Atech;
- Volocopter; and,
- Vertical Aerospace

What are the aims of the Eve Sandbox Project?

Within the Sandbox the Eve-led consortium aims to:

- Develop a concept of operations for safely integrating passenger carrying piloted electric air taxis into low-level airspace, with specific focus on the transportation of passengers from London City to Heathrow airport with stops in between.
- Deliver a tested framework for harmonising airspace, procedures and infrastructure to accelerate the advancement of the Urban Air Mobility (UAM) ecosystem.
- Help the CAA to shape future regulations for UAM operations across the UK.

Visit UK Urban Air Mobility Consortium
for further information on the Eve project
ukairmobility.com

Visit the CAA Innovation Hub
for latest updates, guidance and challenges
caa.co.uk/innovation

The Regulatory Sandbox

Methodology of the Regulatory Sandbox

The Eve Sandbox project is being run in accordance with the principles of the CAA Regulatory Sandbox, which encourages open discussion between participants to identify and work towards addressing the key challenges that innovation can bring in the areas of safety, security and consumer protection.

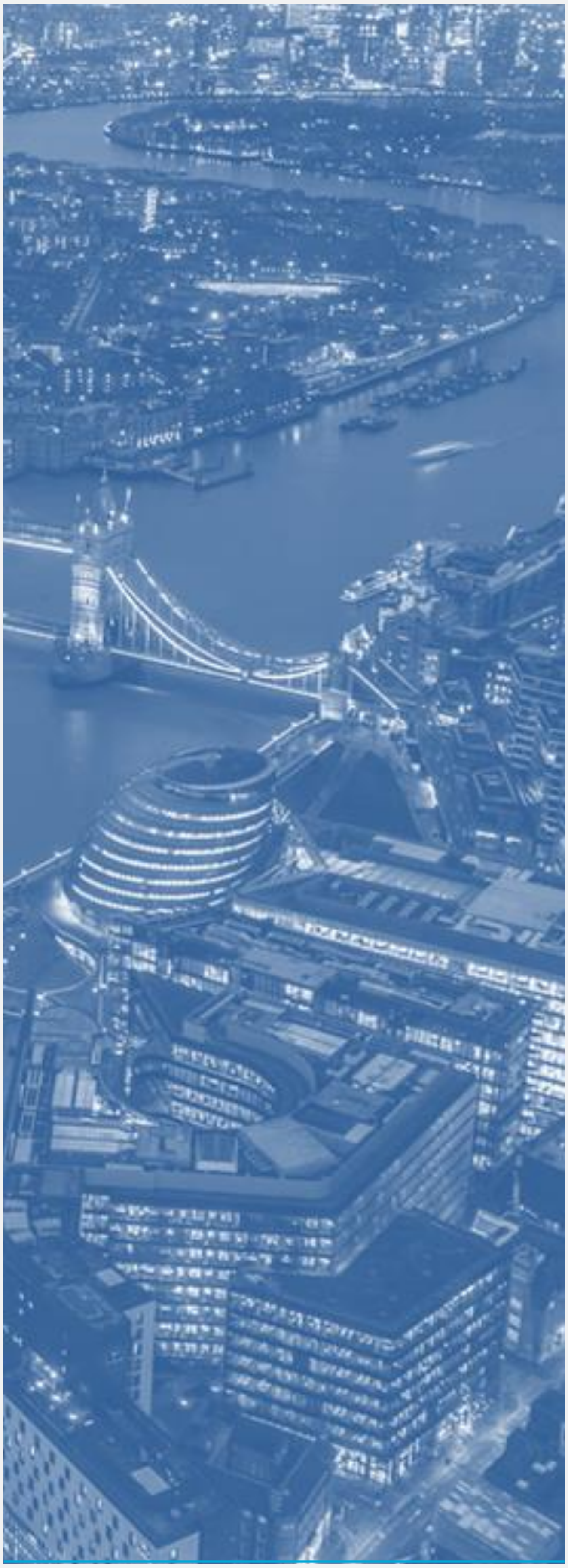
This has involved the Eve consortium describing in detail the use case and its proposed solutions in innovation-focussed workshops with CAA specialists in Airspace Management, Aerodromes, and Flight Operations. Through this two-way dialogue they were able to discuss the applicability of current regulations to the scenarios described, potential key risks to these operations and to explore the delta between the intended operation and the safety requirements.

Sharing lessons from the Regulatory Sandbox

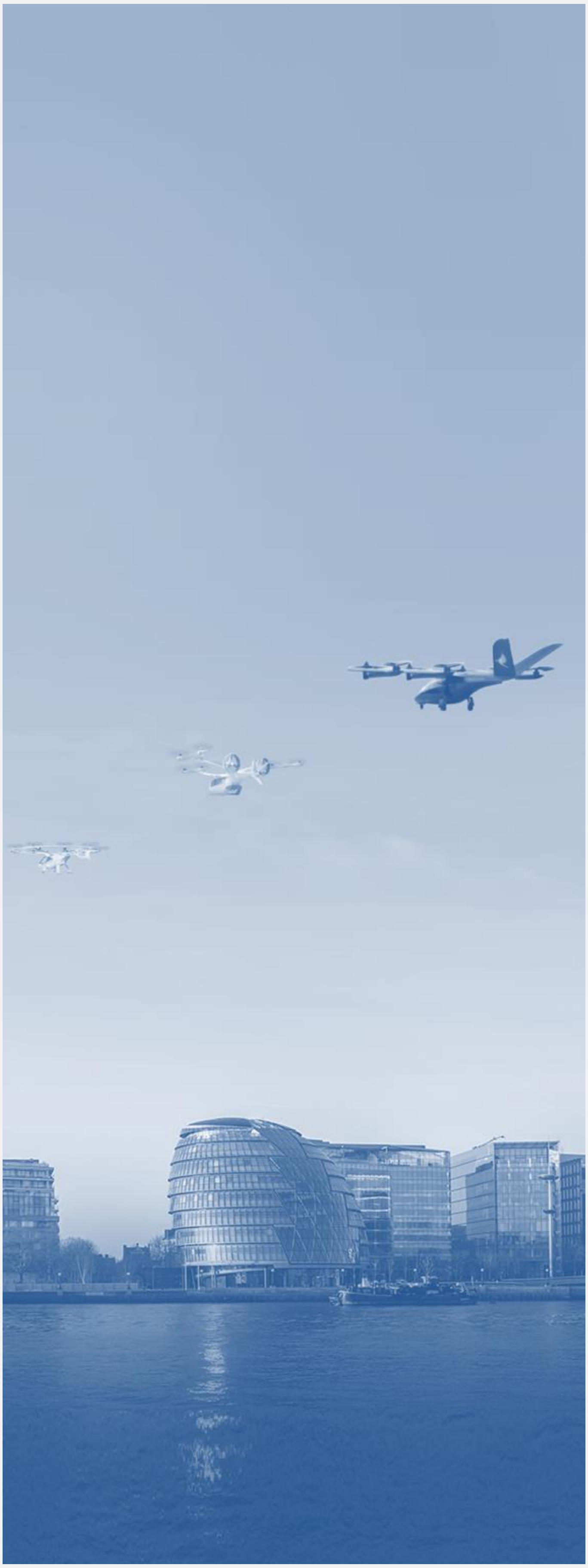
Lessons identified within the Regulatory Sandbox are shared with the industry so that other industry innovators may benefit from understanding the challenges which are key to the CAA and to support the future development of the UK-based aviation sector. It is within this publication that we aim to share the initial findings of the Eve Urban Air Mobility CAA Sandbox project.

Signposting relevant regulations and guidance

Current regulations and principles are signposted to provide a starting point from which to consider the regulatory context which may apply to future operations. Other regulations, guidance and materials will also be applicable to consider.



The Key Challenges



The key challenges for airspace integration

The Eve case study presents a specific use case; transportation of passengers from London City to Heathrow airport with stops in between.

By referring to the specific use case we were able to work towards identifying and understanding some of the challenges of integrating UAM operations into the airspace.

Many challenges were discussed, which broadly fell into the following three high-level areas:

- Exploring the challenges UAM operations at scale may bring.
- Low-level flying in congested built-up environments.
- Understanding how the endurance capabilities of electric Vertical Take-off and Landing (eVTOL) aircraft may impact upon airspace integration.

Fuller appreciation of these challenge areas will play a significant role for the integration of UAM into UK airspace.

Additional factors, including integration of UAM operations on the ground and into ground infrastructure, are also important to consider but are not focused on within this document.

UAM operations at scale

The use case proposes scaled UAM operations, ultimately increasing the traffic density of the target airspace environment. This presents operational, safety and integration challenges to overcome.

Fundamental to this aspect of the use case is how the human performance of operators may be changed when managing a complex network of traffic flows, and how to maintain the fair and equitable access to airspace.

UAM Operations at Scale

Human Performance Complexities in Air Traffic Management

Problem statement

UAM operations in the context of increased traffic levels and complex traffic environments could create additional complexities for air traffic management (ATM) and the provision of air traffic services (ATS).

For example, unscheduled traffic, flights operating under Visual Flight Rule (VFR), different types of aircraft, different sizes of aircraft, flying close to the ground and operating in an obstacle rich environment.

Such added complexity may consequently make deconflicting traffic flows more complex and increase the risk of loss of separation between aircraft, mid-air collision and other accidents. The role of ATS operators in managing traffic flows, tactically deconflicting and managing tactical in-flight changes, will need to be assessed.

Context of existing regulations

ATS (surveillance or procedural) is provided across the UK to various degrees in controlled and uncontrolled airspace, as published in the UK Aeronautical Information Publication (AIP) En-Route (ENR) Part 2 (Air Traffic Services Airspace). This supports the requirements of existing air traffic. Much of the controlled airspace below FL195 is ICAO Class D i.e. Instrument Flight Rule (IFR) flights will be separated from other IFR flights by the ATS, with VFR flights responsible for maintaining their own separation through ‘see and avoid’ principles and known information.

Manual of Air Traffic Services Part 1 (CAP 493) provides further detail on the provision of ATS in the UK.

Important considerations

The operator will need to conduct an assessment to determine what ATS/ATM requirements are necessary to support their operation. The Concepts of Operations must consider traffic management procedures that can maintain acceptable levels of safety in the context of increased traffic density.

Considerations could include:

- The potential need to enhance the minimum equipment requirements to operate in the airspace - in the form of cooperative surveillance and communication technology.
- Appropriate separation minima for eVTOL aircraft vis-a-vis other eVTOL aircraft and existing airspace users.

UAM Operations at Scale

Fair & Equitable Access to Airspace

Problem statement

UAM operations at scale may challenge the principle of providing fair and equal access to airspace. The rapid growth of UAM operations could monopolise access to airspace and exclude other operators.

In the Class D airspace environments being considered by the use case this could cause a perceived disruption to the current status quo and 'Share the Air' principles i.e. the principle that access to the airspace be fair and equitable.

Context of existing regulations

The underlying principle of Class D airspace is that airspace users are expected to share the air. Use references to consider include:

- UK ATS Airspace Classifications, as derived from the Standardised European Rules of the Air (SERA) classification system.
- Safety and Airspace Regulation Group (SARG) Policy Statement on the application of ICAO Airspace Classifications in UK flight information regions.
- CAP 774 UK Flight Information Services.
- CAP 493 Manual of Air Traffic Services Part 1.
- CAP 1616 Airspace Change.

Important Considerations

Concepts of operations should demonstrate how it proposes to maintain fair and equitable access to the airspace for all airspace users.

This may include demonstrating how a new airspace design may be pursued through amendments to current controlled airspace or through forms of special use airspace. With the former enabling higher degrees of integration with other operations.

UAM concepts should consider how existing operations and other new entrants may be accommodated in the airspace.

Where an airspace change is likely to be required, engagement should start at the beginning of the regulatory process, with consultation on airspace designs coming later.

Current regulations and principles are signposted as starting point only and other materials will also be applicable to consider.

Low-level flying in congested urban airspace

The use case proposes the operation of UAM vehicles in low-level airspace.

Vehicles will be operating under a range of meteorological conditions, both Visual Meteorological Conditions (VMC) and Instrument Meteorological Conditions (IMC).

Fundamental to this aspect of the use case is the need to understand the risk of operating within the obstacle environment, in close proximity to other aircraft operations and in a range of weather conditions. This will also call for additional consideration to be given to minimising the impact of the operation on communities on the ground.

Low-Level Flying

Flight within the Obstacle Environment

Problem statement

Low-level operations pose a risk of collision with permanent and temporary obstacles, of controlled flight into terrain and of loss of control resulting in control induced collisions.

Current Target Levels of Safety (TLS) are designed for operations above the obstacle environment. Operating at altitudes 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 1868). 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 then consider and determine any new applicable TLS for such scenarios.

Context of existing regulations

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 e.g. within the London and London City Control Zones (CTRs), but it would need to be determined if these could also apply to UAM aircraft.

Similarly, under the same ruleset, aircraft usually must not be flown closer than 150 metres (500 feet) to any person, vessel, vehicle or structure except with the permission of the CAA.

- ICAO Annex 2 Rules of the Air 3.1.2, 4.6 and 5.1.2.
- SERA.3105 Minimum Heights and specifically; SERA.5005(f) Visual Flight Rules, SERA.5015(b) Instrument Flight Rules.
- UK AIP ENR 1.2 and ENR 1.3.

Important Considerations

UAM concept of operations must propose mitigations to address the risks exposed.

Risk areas to consider include:

- The risk of incidents and because of; controlled flight into terrain (CFIT), loss of control in flight (LOC-I) and obstacle collisions, considering both permanent (i.e. buildings) or temporary (i.e. cranes) obstacles.
- The risk to third parties from such incidents and accidents.
- Implications of both day and night operations.
- Pilot performance within the obstacle environment (e.g. ability to maintain lateral separation from closely spaced obstacles).
- UAM vehicle performance within the obstacle environment. Including, if an eVTOL, transition from wing-based flight to hover.
- The aerodynamic effects of flying in close proximity to buildings and structures.
- Minimum and maximum en-route altitude for UAM vehicle flight.

Flight in Close Proximity to Other Low-Flying Traffic

Problem statement

UAM operations flying in close proximity to other low flying traffic (such as remotely piloted aircraft systems (RPAS) operations and helicopters) may increase the inherent risk of mid-air collision and other accidents induced by loss of control or taking avoiding action. Such risks will require thorough assessment and appropriate mitigation, considering the ability of UAM vehicles to 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) as required under the rules of the air. This may need to take into account vehicle performance e.g. specifically that, depending on the vehicle design, eVTOLs can be less manoeuvrable than helicopters during the cruise phase of flight.

Context of existing regulations

The following regulations provide additional context:

- CAP722 Unmanned Aircraft System Operations in UK Airspace – Guidance.
- SERA.8010, SERA.8012.
- Air Navigation Order 2021 No. 879.

Important Considerations

UAM concepts of operations must consider the risks of flying at a low level in close proximity to other traffic and propose mitigations to address the risks exposed. Risk areas to consider include i.e.:

- The risk of incidents and accidents because of; loss of control in flight (LOC-I) and mid-air collision.
- The risk to third parties from such incidents and accidents.
- Pilot performance (e.g. ability to maintain lateral separation from other traffic, to take avoiding action and make way for priority traffic).
- UAM vehicle performance (e.g. the manoeuvrability of vehicles and the ability to avoid other traffic and make way for priority traffic).
- The wake turbulence interactions of flying in a confined and mixed-use airspace.

Low-Level Flying

Operating in a Range of Meteorological Conditions

Problem statement

The complexity of flying at low level altitudes is heightened if operating in limited visibility and poor weather conditions.

In such conditions, pilots may have a reduced ability to detect and avoid obstacles and other aircraft, increasing the risk of incidents and accidents. In such conditions greater reliance is often placed on technical solutions, but these must have appropriate accuracy and robustness.

Context of existing regulations

The following regulations provide additional context:

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

Important considerations

The concept must propose suitable technical, operational or procedural mitigations to the risks of flying at low altitude in congested airspace in all weather conditions.

It is important to consider flight rules from the perspective of what they mean to the pilot, in terms of their practical implementation in such conditions. For example, visual flight rules rely on it being possible for pilots to see and follow the appropriate rules of the air to avoid risks and maintain appropriate separation.

Any alternative means of complying to the rules of the air or flight rules will need to consider the principles of current rules.

Low-Level Flying

Social Licence

Problem statement

Gaining social acceptance and support for the new technologies, and particularly public services, is recognised as critical to the future success of the UAM industry.

Whilst there are many benefits of UAM use cases, the combination of low-level flight and traffic density also heightens the complexity of gaining social acceptance.

Context of existing regulations

The following regulations/guidance provides further context to the problem statement.

- 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.
- CAP1900 Social Licence to Operate: Concept Guide for New Technologies

Important Considerations

UAM concepts will need to show an understanding for the noise and visual intrusion implications of flying at low-level, considering the effect on communities and businesses on the ground, including privacy laws.

Specific consideration would need to be given to those in the vicinity of landing sites and overflown communities. For example, this may include investigations into the following:

- What are the proposed flight paths and profiles of departure and approach routes?
- What is the operational environment in the vicinity of landing sites and enroute, including both temporary and permanent features?
- What is the demographic of the overflown third parties (residential, business etc.) and how respite may be provided to them?
- How might communities be engaged?

Flight Endurance of eVTOL aircraft

The use case proposes the development of UAM vehicles, which are expected to be eVTOL and hybrids. Such aircraft have different performance characteristics compared to more traditional aircraft; specifically when considering their endurance during flight.

Fundamental to this aspect of the use case is that this may have implications if a vehicle is required to deviate from its flight plan.

Flight Endurance of eVTOLs

Problem statement

To safety integrate into the airspace, the performance capabilities of eVTOL aircraft will need to be considered in a variety of scenarios.

eVTOL aircraft presently have different performance characteristics compared to more traditional aircraft; specifically when considering their endurance during flight. Battery propulsion is an emerging technology that offers one of several solutions to achieving net zero aviation emissions. However, presently eVTOL aircraft utilising this option may have a reduced flight endurance when compared to aircraft which use conventional propulsion methods.

Considering the above, UAM operators will still need to be able to sufficiently respond to any real-time changes to their planned route, changes which could elongate flying time and/or distance outside of the vehicles endurance limits. Such deviations may occur because of traffic avoidance, weather avoidance, compliance with ATC instructions or other disruptions to the traffic flow that may require deviation or holding, such as delays on the ground or in the air.

The potentially limited range and diversion capabilities of eVTOL aircraft may lead to challenges in finding suitable alternate landing sites, especially if airspace issues affect large numbers of aircraft simultaneously.

Context of existing regulations

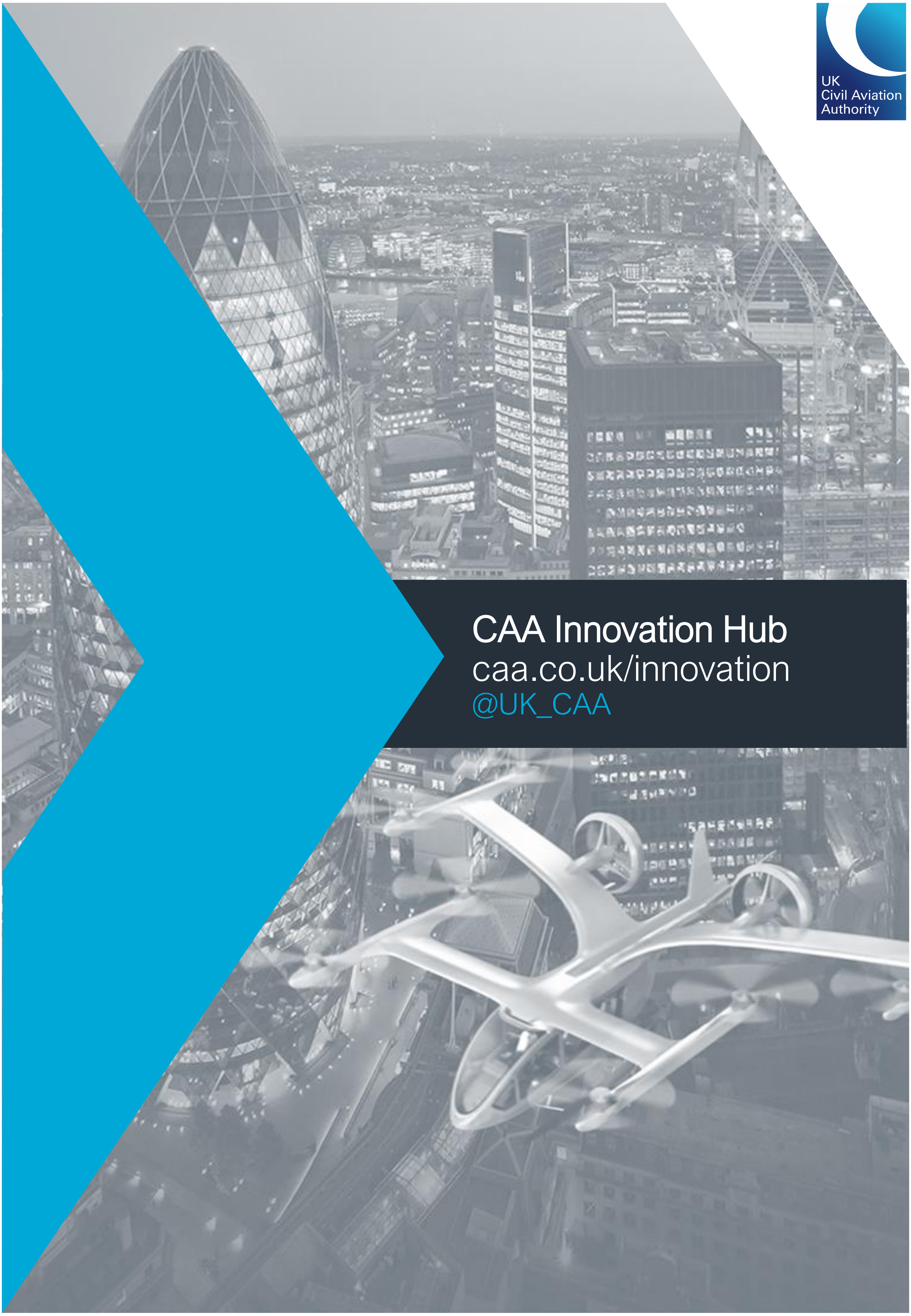
- SERA.8020.
- CAP493 Section 1.
- ICAO Annex 14 vol 2.

Important considerations

UAM concepts of operations will need to consider the ability of UAM vehicles to deviate from their planned route. Consideration should be given to the following, inter alia:

- Providing assurance of a place to land prior to take off and alternate landing sites, including their availability, efficiency, and distribution of such sites.
- Energy reserve needs for different flight and landing scenarios.
- The tolerance of eVTOLs to different meteorological conditions.
- The manoeuvrability of eVTOL vehicles.
- Implication of aircraft wake turbulence characteristics.
- Impact of turbulence from buildings on handling qualities of eVTOL vehicles.
- ATM requirements/support when deviating.
- Ground handling services required at alternate landing sites.

Deviating from Flight Plan



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