Electronic Conspicuity – Initial Technical Concept of Operations (EC ConOps) 2025

CAP 3140

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Contents

Abbreviations

AAM	Advanced Air Mobility
ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependent Surveillance - Broadcast
ADS-L	Automatic Dependence Surveillance - Light
ANSP	Air Navigation Service Provider
AMS	Airspace Modernisation Strategy
Arc	Airspace Risk Category
ATC	Air Traffic Control
ATS	Air Traffic Services
BVLOS	Beyond Visual Line of Sight
C2	Command and Control
CAA	Civil Aviation Authority
CAP	Civil Aviation Publication
CAS	Controlled Airspace
CNS&S	Communications, Navigation, Surveillance and Spectrum
DAA	Detect and Avoid
DfT	Department for Transport
DO-260	Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance - Broadcast (ADS-B) and Traffic Information Services - Broadcast (TIS-B)
DO-282	Minimum Operational Performance Standards for Universal Access Transceiver (UAT) Automatic Dependent Surveillance – Broadcast
DO-396	Minimum Operational Performance Standards for Airborne Collision Avoidance System sXu (ACAS sXu)
EASA	European Aviation Safety Agency
EC	Electronic Conspicuity
EMIT	European Monitoring of Interrogators and Transponders

eVTOL	Electric Vertical Take-Off and Landing
FHA	Functional Hazard Analysis
FID	Flight Information Display
FIS-B	Flight Information Service - Broadcast
FLARM	A collision warning system
GA	General Aviation
GANP	ICAO Global Air Navigation Plan
GASCo	General Aviation Safety Council
GI	Ground Infrastructure
GNSS	Global Navigation Satellite System
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
Kt	Knot
LTE	Long-term evolution (a wireless broadband communications standard)
MAC	Mid-Air Collision
MHz	Megahertz
MLAT	Multi-Lateration
MOR	Mandatory Occurrence Report
MTOW	Maximum Take-Off Weight
NAC	Navigation Accuracy Category Position
NACv	Navigation Accuracy Category Velocity
NIC	Navigation Integrity Category
NISC	National IFF/SSR Committee
NTD	Non-Transponder Device
Ofcom	The regulator for the communications services in the UK
PNT	Position, Navigation, Timing
RCE	Reduced capability equipment

RTCA	founded in 1935 as the Radio Technical Commission for Aeronautics, now referred to simply as “RTCA”
SA	Situational Awareness
SA	Supplementary Amendment
SARPS	Standards and Recommended Practices
SDA	System Design Assurance
SERA	Standardised European Rules of the Air
SIL	Source Integrity Level
SORA	Specific Operations Risk Assessment
SRD860	Short-range Device operating in the 860 MHz band
SSR	Secondary Surveillance Radar
TIS-B	Traffic Information Service - Broadcast
TRA	Temporary Reserved Area
TSO	Technical Standards Order
TSO-154	Universal Access Transceiver (UAT) Automatic Dependent Surveillance - Broadcast (ADS-B) Equipment Operating on the Radio Frequency of 978 Megahertz (MHz)
TSO-C166	Extended Squitter Automatic Dependent Surveillance - Broadcast (ADS-B) and Traffic Information Service - Broadcast (TIS-B) Equipment Operating on the Radio Frequency of 1090 Megahertz (MHz)
TSO-C199	Provides the requirements for the applicable equipment class for traffic awareness beacon systems (TABSs)
UA	Unmanned Aircraft
UAS	Unmanned Aircraft Systems
U-Space	A system of digital services and procedures designed to manage and ensure the safe and efficient use of airspace by a large number of UAS
UAT	Universal Access Transceiver
USA	United States of America

UTM	Unmanned Aircraft Systems Traffic Management
UK	United Kingdom
VFR	Visual Flight Rules
VLOS	Visual Line of Sight

Executive Summary

Introduction

Electronic Conspicuity (EC) is an essential element to enhance airspace safety and situational awareness by enabling aircraft to be detected electronically. This detection data can be used to reduce mid-air collision risk where appropriately acted upon. While EC improves situational awareness and air-to-air and air-to-ground detection, EC alone cannot fully mitigate mid-air collision risks. This document will focus on the dual aims of enhancing manned aircraft situational awareness and enabling detect-and-avoid for Unmanned Aircraft Systems (UAS).

EC was initially developed in the 1940s with the introduction of radar technologies and then transponder technology. More recently, many forms of EC, including 'reduced capability equipment'[1] (RCE) and 'non transponder devices' (NTD)[2] have played a part in improving situational awareness for General Aviation (GA). In the future, EC will play a crucial role in facilitating the safe integration of beyond visual line of sight (BVLOS) UAS and other emerging aviation technologies with existing users. For the reasons set out in Appendix C, this document deals mainly with the standards of both transponder based and RCE/CAP1391 ADS-B devices.

While a key enabler, it is important to note that EC is just one part of a broader set of solutions supporting the introduction of Beyond Visual Line of Sight (BVLOS) Unmanned Aircraft Systems (UAS). This includes capabilities such as:

- Detect and Avoid (DAA)
- Command and Control (C2) Links
- System-Wide Information Management (SWIM)
- UAS Traffic Management (UTM)
- Ground Infrastructure (GI)
- Communications

[1] RCE is a definition contained within ICAO doc 9871, setting an international standard for identifying equipment that met a subset of the SARPS, and that had a 'reduced capability'. Such equipment could include TSO-C199 and CAP1391 devices

[2] Non transponder devices are EC technology that specifically exclude the use of a secondary surveillance transponder device.

This document therefore, is one part of a wider plan for the implementation of the Airspace Modernisation Strategy (AMS) part 2 deliverables as set out within UK-AM/4 (Integration) and UK-AM/7 (Future Surveillance). It should be noted that this EC ConOps is an iterative document, and that this version is the first publicly available version which sets out the UK's current position on Electronic Conspicuity.

The technical positions set out within this initial version are likely to evolve following consultation and extensive testing, before becoming policy at the end of 2027. This should be considered when making any commercial or equipment purchasing decisions.

This EC ConOps sets out nine positions that the CAA is proposing to adopt as technical requirements for the airborne use of EC in the UK. These focus on equipage requirements, device standards and how the benefits of EC will be safely incorporated into UK airspace[3]. It also outlines our short-term and longer-term steps for EC implementation. The short-term positions are effectively the concept test phase, and the longer-term strategy will become 'business as usual' after completion of the test phase. The CAA will be working closely with industry throughout the test phase to feed-back the findings of the implementation of our positions as set out below.

This document presents clear, evidence-based[4] proposals that provide a realistic and proportionate pathway for successful adoption. It allows EC to remain one of the key enablers of airspace modernisation, while it continues to evolve alongside technological advancements and regulatory developments in the UK. Maintaining safety, cost-effectiveness, scalability, and accessibility across all airspace users will remain a key priority in shaping its long-term future.

This initial Technical Concept of Operations is the first of several planned iterations that will define the technical requirements and proposed positions for the use, installation, and performance of EC devices on aircraft below 5700Kg in UK airspace. As an early version, it does not cover all elements typically found in a complete Concept of Operations. These areas will be developed in future updates, shaped by stakeholder feedback and operational testing – resulting in changes to this and related documents.

It is important to note that, while EC is a key enabler for integrating manned and UAS into an airspace volume, EC has limitations that are set out within this document. Some technology in use today may not meet requirements identified for tomorrow. These requirements and therefore the technology necessary will be defined in further iterations of this document.

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[3] UK airspace in this context includes the volumes of the London and Scottish FIRs.

[4] See chapter 2 - Understanding the Evidence Behind our Positions

Positions on EC – at a glance

The following position statements set out the key resulting concepts which are described in more detail in chapter 2. Although there will be a range of airspace scenarios and risk[5] within non - segregated airspace, it is important to set a baseline standard of equipage that supports an airspace architecture concept for manned and unmanned aircraft that is achievable and will address the largest range of mitigations.

This document does not set out detailed airspace structures or classifications for the use of EC. For the purpose of this document, the term 'non - segregated airspace[6]' refers to the volumes of UK airspace where BVLOS UAS will be operating alongside other airspace users, with EC acting as a mitigation.

Airspace structures and classifications will be addressed separately in the forthcoming airspace concept of operations. This will set out how different types of airspace will support the integration of EC-enabled operations. This, along with all the CAA's work in this arena, will provide a joined-up picture of how EC will function within the UK's airspace to support safer and non - segregated flight.

The Role of EC in UK Airspace

Position 1. EC will be an enabler for both air-to-air tactical and strategic deconfliction within non - segregated airspace. Tactical deconfliction will be the primary mitigation, while strategic deconfliction will enhance risk management. Ground infrastructure will enhance both mitigations where appropriate.

Airspace Architecture

Position 2. The overall performance of the EC system will be enhanced, where appropriate through a combination of interoperable airborne and ground-based[7] systems that build on existing architecture.

Position 3. EC with an appropriate level of accuracy and performance set out in this document will aspire in the short term to support operations for the following:

- DAA by Unmanned Aircraft
- Where equipped, position information to and from some ANSPs (or future UTMSP – policy under development)
- Traffic / situational awareness for manned aircraft

[6] Reference ICAO doc 10019 (Manual on Remotely Piloted Aircraft Systems)

[7] Reference the Ground Infrastructure ConOps (under development)

- Some limited interaction with traffic collision avoidance system (TCAS) for manned aircraft[8]

Equipage requirements

Manned aircraft specific

Position 4. Within non - segregated airspace, aircraft operating at <140 knots (Kts) Indicated Air Speed (IAS) must use 1090MHz ADS-B devices emitting a SIL and SDA of at least 1, such as (for example) some CAP1391 devices. Alternatively, a TSO-C112 and TSO-C166 compliant transponder with extended squitter connected to TSO-C199 class B or TSO-C145 Global Navigation Satellite System (GNSS)[9] source.

Position 5. Within non - segregated airspace, aircraft operating at >140kts IAS must use a Mode S transponder with ADS-B Extended Squitter functionality and SIL = 3, SDA = 2, typically a TSO-C112 and TSO-C166 compliant transponder connected to a TSO-C145 GNSS source.

Position 6. Any ADS-B – IN carriage for manned aircraft will remain a personal or organisational risk-based choice for the manned aircraft operator.

Unmanned specific

Position 7. Within non - segregated airspace, UAS in the Specific Category operating BVLOS, must emit a 978MHz UAT ADS-B signal. The device should function in accordance with the RTCA minimum performance standards DO-282B, (It is expected that DO-282C will be the standard from 2027) and of a minimum power yet to be set out within CAP1391 supplementary amendment 2025/01. Emissions must meet SIL and SDA of at least 1.

Position 8. Specific category UAS operating BVLOS in non - segregated airspace must be equipped to receive ADS-B 1090 MHz and 978 MHz UAT in order to detect both manned and unmanned aircraft.

Responsibility for EC Installation and Efficacy

Position 9. Aircraft operators, both manned and unmanned, are responsible for ensuring that their EC device is installed in accordance with the equipment manual and any CAA advice. Pilots must also ensure their device is functioning effectively.

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[8] Hybrid ACAS II systems can use 1090MHz Extended Squitter (ADS-B) emissions to supplement the TCAS function which would historically rely on a 1030MHz interrogation. *(limited to display on some systems – no TA or RA with ADS-B alone)*

[9] A common GNSS system is the US GPS system, but there are other systems worldwide

Next Steps

The successful implementation of EC in the UK requires balancing immediate priorities to validate our policy positions with a longer term (beyond 2027) goals to make sure the CAA keeps up with technological advancements and refine our standards. Any future changes to policy must not negatively impact existing infrastructure and associated operations.

In the short-term (2025-2027), the focus will be on validating our positions through test, trials and research, as well as continuous stakeholder engagement. Real-world testing will assess EC's effectiveness as part of a tactical and strategic DAA[10] system, ensuring that policy assumptions hold true in operational environments. Trials will continue to explore air-to-air interactions between different EC-equipped aircraft and assess how EC can support DAA and UTM integration. The findings will inform regulatory refinements and policy updates, ensuring that EC remains a credible risk mitigation.

In addition, operator training and, for some RCE, installation guidance will be prioritised to ensure EC devices perform in an appropriate manner, are installed and used effectively. The CAA will develop training materials based on industry findings, human factors research, and real-world implementation challenges to improve EC's operational effectiveness.

In the longer term, the focus will shift towards enhancing EC technology and expanding its role in airspace modernisation. This will include exploring the development of next-generation ADS-B EC devices with higher performance standards and greater interoperability. Development of new RCE EC equipage standards and certifications, such as transponder-independent EC devices will be required. These longer-term aspirations will be balanced against existing standards and spectrum congestion capabilities. The aim being to produce standards that will be able to work with older versions or previous iterations of the technology.

This document presents the UK CAA's direction for EC, establishing firm policy positions for today, while allowing its continued evolution.

[10] Detail set out in CAP3015

Chapter 1
Introduction

Context

1.1 The transmission, reception and display of a position and state vector between aircraft can provide a basis for the operators of those aircraft to enhance their situational awareness of other traffic. This strengthens the principle of 'see and avoid' by adding the ability to 'detect and be detected'[11]. To be most effective, 100% of users operating in a designated block of airspace, should use compatible EC devices and be able to be detected by others. This ConOps does not propose routine equipage by Visual Line of Sight (VLOS)/Open Category UAS, as their mitigation is visual detection. EC will also play its part in enabling aircraft to integrate their operations with new airspace users who cannot 'see and avoid'. There are many occasions where aircraft come into proximity without the pilots seeing each other's aircraft (or seeing them very late)[12]. Research shows[13] that smaller, mostly specific category UA, cannot be visually detected by a manned aircraft at sufficient ranges to avoid a collision. The safety mitigation provided by EC is, therefore, dependent on correctly installed and functioning EC equipment in areas where BVLOS operations are taking place.

1.2 The regulatory landscape that deals with the related aspects of EC is complex. The aspects that this paper will discuss, include:

- The design standards of the various EC technologies
- The certification and related quality indicators of the various EC devices
- SERA[14]
- DAA concepts

[11] Detect and Avoid is discussed in appendix C

[12] GASCo Report CAP 2583

[13] A4A/NATS, Barton study, 2019

[14] UK Standardised European Rules of the Air

SERA (UK Reg (EU) No 923/2012 (as amended)) applies to every aircraft operating in UK airspace regardless of type or state of registration.

- Risk assessments, including quantitative SORA[15] ground and air risk, Functional Hazard Analysis (FHAs) and other qualitative assessments
- ICAO SARPS[16]

Scope

1.3 This paper aims to set out a *short-term* and *long-term* plan for EC in the UK, taking its place in setting the UK on a more certain path to airspace integration with new technologies and improving safety for existing manned operations. This will aim to specify the use, carriage and performance of EC in the existing fleet.

1.4 When dealing with UAS, there are three categories[17] and two distinct operating environments. In summary:

- Open category: there is no requirement for specific approvals from the CAA but in most cases, operators must register and get a flyer ID. Remote pilots must fly *within visual line of sight* (VLOS).
- Specific category: covers flying (operations) with a greater level of risk than the Open category. Operators must obtain an Operational Authorisation from the CAA before carrying out operations in the Specific category. Operators can fly within *visual line of sight* or *beyond visual line of sight (BVLOS)*.
- Certified category: covers operations that present an equivalent risk to that of manned aviation; because of this they are be subjected to the same regulatory regime.[18] This document does not deal specifically with certified category UAS as it is assumed that certified category systems will use the same levels of equipage as manned aircraft flying IFR.

1.5 The intention within this paper is to mainly advise on possible equipage needs across the GA fleet to improve safety, and to enable integrated specific Category UAS operations. The CAA deals with the interaction of manned-to-manned aircraft as well as manned to UAS, with the intention of providing mitigation, using EC, to reduce the risk of mid air collision (MAC).

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15 SORA – Specific Operations Risk Assessment - The SORA is a methodology for the classification of the risk posed by a drone flight in the specific category of operations and for the identification of mitigations and of the safety objectives.

16 ICAO SARPs (Standards And Recommended Practices) are technical specifications adopted by the Council of ICAO to achieve uniformity in regulations, standards, procedures, and organization in international civil aviation

17 CAP722 - Unmanned Aircraft System Operations in UK Airspace – Policy and Guidance

18 The military also operate UA and have an increasing requirement for this to be BVLOS. Whilst not regulated by the UK CAA, they nonetheless need to be catered for in the EC landscape

1.6 Whilst the CAA deals with the air-to-air EC interaction between aircraft as well as the air-to-ground scenarios, other workstreams are in place that intend to support the wider AMS, including Ground Infrastructure, which will publish a separate but related paper.

Background and history

1.7 A Europe wide mandate for the emission of ADS-B from aircraft >5700Kg or 250Kts is set out in UK SI 1207/2011. Our work on RCE EC began in the mid-2010s as a method of improving safety and situational awareness for General Aviation (GA) traffic, especially while operating outside controlled airspace. Several EC devices, and combinations thereof, have gained traction and are in use in UK and international airspace today. Market forces and the needs of operators have dictated different solutions for different sectors of aviation. This has led to significant safety gains for some sectors of GA. As an example, FLARM[19], is playing a part in reducing the glider-glider collision rate. Operating at relatively slow speeds, particularly for sailplanes, the system is especially designed to address an operational need. However, it does highlight that an air-to-air interoperable solution can have real safety benefits. In a recent AAIB annual safety review[20] when dealing with GA, a summary quotes “The mid-air collision rate in the UK is considerably higher, by a factor of four, than in the USA. A Regulus Group report[21] “Measured Impact of ADS-B in applications on General Aviation and Air Taxi Accident Rates” within its conclusion stated that “The results [ ] clearly indicate that aircraft installed with ADS-B - IN capable equipment are experiencing a reduced accident rate compared to those without this equipment.” A point worth noting is that the above indicators of reduced Mid-Air Collision (MAC) rates have taken place despite a likely lack of specific training for pilots and operators.

1.8 In a recent UK Airprox Board report[22] the final comments included that one of the six consistently highlighted key areas of concern included the compatibility of EC. This is also highlighted in the GASCo Human Factors’ report[23] which states that there are many different combinations of various devices.

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[19] FLARM is a blended word from ‘Flight Alarm’. It is a technology initially designed for glider pilots to avoid mid-air collisions.

[20] AAIB annual safety review 2023 - AAIB_Annual_Safety_Review_2023.pdf

[21] Measured Impact of ADS-B In Applications on General Aviation and Air Taxi Accident Rates available from the AOPA website

[22] UK Airprox Board analysis of airprox in UK airspace - Report no. 39 - bluebook39.pdf

[23] New study on Electronic Conspicuity published by aviation regulator | Civil Aviation Authority

1.9 Beyond the risk of mid-air collision (MAC), the UK Airspace Modernisation Strategy (AMS) and the DfT Future of Flight initiatives seek to leverage EC technologies to enable integrated Beyond Visual Line of Sight UAS operations and potentially other novel technologies, including advanced air mobility (AAM), eVTOL operations. This development introduces specific requirements for UK EC equipage which have been incorporated into the latest EC studies.

1.10 In December 2022, the Department for Transport (DfT) and the CAA published a joint statement detailing their support for the recommended adoption of Automatic Dependent Surveillance-Broadcast (ADS-B) operating manned aircraft and 978 MHz for Unmanned Air Systems (UAS) respectively, utilising existing global standards.

1.11 This ConOps focusses on the mitigations EC can provide using existing technology, as well as proposing requirements that could enable a more accurate, reliable and robust system for the future. The EC subject is extremely complex with many competing technologies, standards, compatibility issues and stakeholder requirements. This document attempts to distil many complex reports and related studies into the main conclusions which are presented to the reader. Whilst the conclusions in this document have been made with the benefit of practical experience and as a result of research, they will not present a panacea, and the reader will soon find that EC in any of its forms is not a perfect solution for all applications. Nonetheless, the CAA attempts to set out the benefits that EC can provide.

EC Mandate

1.12 This paper defines the technical capabilities, equipage standards, and operational requirements for EC for the purpose of operating in non - segregated airspace.

1.13 Alongside this work, the CAA and DfT are conducting a separate exercise which explores the implementation of a potential extension to the existing EC Mandate. This parallel work aims to understand, in detail, the impact of potential mandate options on aviation in the UK and the processes and resources required for its implementation.

1.14 This document does not set out the details of how a future mandate may be implemented. However, should this separate exercise result in a potential mandate the Government wishes to endorse, the CAA will initiate additional work including appropriate consultation, stakeholder engagement, and a full regulatory assessment.

Call for Evidence on EC Mandate

1.15 Although this document does not define the EC mandate itself, the consultation for this paper does include a brief call for evidence on specific aspects of the potential mandate. This early engagement aims to gather stakeholder views to help us inform future policy discussions.

1.16 By separating the technical framework from mandate discussions, this paper ensures a clear focus on defining EC's role in airspace modernisation while allowing future mandate discussions to be independently shaped.

Chapter 2
Proposed EC Positions

2.1 This section outlines our proposed positions on EC and details the reasoning behind these.

Understanding the Evidence Behind our Positions

2.2 The positions presented below are supported by evidence borne from several key studies and reports, including:

- **Electronic Conspicuity (EC) Consolidated Study Report (2024) –** A multi-workstream study assessing airspace risk, EC performance, human factors, and integration with ground infrastructure. CAP3139 brings together all these studies and presents findings in a consolidated document.
    - **Egis Report (CAP2498 A, B, and C, (2022)) –** A study defining minimum EC standards, assessing industry perspectives, and recommending regulatory pathways for EC adoption.
    - **Mode-S Transponder and EC Equipage Study (2023) –** An analysis of EC and transponder equipage rates across UK airspace between 2018 and July 2024.
    - **GASCO Human Factors Report (2022) –** An exploration of how GA pilots interact with EC systems, highlighting challenges in data interpretation and cockpit display limitations.
- **Aviation Innovation centre Report on Altitude Reporting (2023) –** A study assessing the accuracy of ADS-B altitude reporting, particularly for CAP1391 devices and the impact of cockpit static pressure variations.
    - **CAP 1391 (Latest version 2021) –** sets out recommendations on the minimum capability required of an RCE EC device.

2.3 Our goal in this paper is to present our positions in a clear manner, making them accessible to a wide range of stakeholders without overwhelming them with technical detail. However, The CAA recognises that many readers may wish to explore the supporting research outlined above in greater depth and to understand our reasoning in more detail.

2.4 For those seeking a more comprehensive understanding, the CAA encourages referring to the following Annexes that include all of the data that underpins our positions, links to the relevant studies, as well as deeper exploration of the conclusions.

- Annex A: Strategic and Regulatory Drivers for EC
- Annex B: Summary of evidence and reports used to support our proposals
- Annex C: Regulatory, Technical and Airspace Integration Considerations for EC Implementation

The Role of EC in UK Airspace

Position 1. **EC will be an enabler for both air-to-air tactical and strategic deconfliction within non - segregated airspace. Tactical deconfliction will be the primary mitigation, while strategic deconfliction will enhance risk management. Ground infrastructure will enhance both mitigations where appropriate.** [24]

2.5 As ADS-B EC enables aircraft to transmit their location and state vector, it allows operators to detect and respond to potential conflicts. For UAS, EC serves to replace traditional see-and-avoid, which has known limitations[25].

2.6 Tactical deconfliction provides real-time air-to-air collision avoidance, with systems like FLARM and ACAS issuing short-term warnings before potential conflicts. ADS-B devices can support a detect and avoid functionality, depending on the ADS-B In standard and processing systems in use.

2.7 Strategic deconfliction offers a broader, preemptive approach, allowing conflict resolution before aircraft come into close proximity. Pre-flight planning and deconfliction tools already exist. However, the CAA also views ground-based EC infrastructure as an important step towards providing pilots and operators with information to improve strategic conflict management.

2.8 This position, therefore, enables a dual - layered approach to avoiding mid-air collision, through the provision of real-time data to inform pilots and remote pilots on decisions regarding strategic and tactical conflict management

[24] Strategic and Tactical deconfliction – reference CAP3015 DAA policy concept

[25] It has been proven by many reports that the conspicuity of medium sized specific category UAs is such that traditional see-and avoid does not provide useable mitigation to mid-air collision. (A4A/NATS report 2019)

EC Device Standards

Position 2. The overall performance of the EC system will be enhanced, where appropriate through a combination of interoperable airborne and ground-based systems that build on existing architecture[26].

2.9 Devices approved in CAP1391 provide a cost-effective, accessible EC solution but have known and measured limitations of effective signal transmission and reception reliability. The EC Consolidated Study Report (CAP3139), including CAP1391 Evaluation identified that these constraints reduce their effectiveness. A new ground-based network[27] will supplement Reduced Capability (RCE) Equipment, such as CAP1391, enhancing detection where required and mitigating the reduced effectiveness particularly in higher risk airspace.

Airspace Architecture

Position 3. EC with an appropriate level of accuracy and performance set out in this document, will aspire in the short term, to support operations for the following:

- **DAA by unmanned aircraft**
- **Where equipped, position information to and from some ANSPs (or future UTMSP – policy under development)**
- **Traffic / situational awareness for manned aircraft**
- **Some limited interaction with TCAS systems for manned aircraft[28]**

2.10 The AMS outlines EC's role in enhancing airspace safety, but its application is currently limited to specific operational areas. The EC Consolidated Study Report highlights that EC can serve as part of the system (including DAA, improving situational awareness for manned, UTM services etc) that mitigates mid-air collision risk in low-risk environments[29] but is not sufficient as a standalone solution in higher-risk airspace where additional surveillance and ATC involvement may be required.

[26] See Appendix C

[27] Set out in part in Appendix C – Ground infrastructure

[28] `Some Hybrid ACAS II systems can use ADS-B emissions to supplement their function

[29] Different risk environments set out in CAP3015, including links to the quality indicators of ADS-B within the data integrity requirements section

2.11 Further engagement, research and testing, including sandbox trials in this accommodation phase[30] will refine EC's role and assess its effectiveness in broader applications.

Equipage requirements

Manned specific

Position 4. Within non - segregated airspace, aircraft operating at <140 knots (Kts) IAS must use 1090MHz ADS-B devices emitting a SIL and SDA of at least 1, such as (for example) some CAP1391 devices, alternatively a TSO-C112 and TSO-C166 compliant transponder with extended squitter connected to TSO-C199 class B or TSO-C145 GNSS source.

Position 5. Within non - segregated airspace, aircraft operating at >140kts IAS must use a Mode S transponder with ADS-B Extended Squitter functionality and SIL = 3 and SDA = 2, typically a TSO-C112 and TSO-C166 compliant transponder connected to a TSO-C145 GNSS source.

2.12 Aircraft operating at lower speeds require shorter detection distances, making reduced capability equipment suitable. ICAO Annex 10 provides a precedent for using different transponder standards based on operational requirements. Many slow-moving aircraft lack cockpit space or sufficient power for certified equipment, and their lower risk profile supports the use of reduced capability EC devices.

2.13 For faster-moving aircraft, higher-performance EC devices are necessary for the following reasons:

- Increased closing speeds require a larger detection range and accuracy to allow for timely avoidance manoeuvres.
- Altitude reporting is less reliable in faster aircraft due to static pressure variations in the cockpit.
- Higher speeds result in greater impact energy, increasing risk from collision.

2.14 The proposed policy strikes a balance between ensuring high-performance EC for fast-moving aircraft and cost-effective solutions for slow-moving aircraft. The 140kt speed is derived from the SERA.5001 VFR rule which reduces speed for VFR traffic for reaction and manoeuvre time when visibility is reduced. There are other parallels with the class of transponder required for aircraft flying at <15000'

[30] Airspace Policy Concept: Airspace Requirements for the Integration of Beyond Visual Line of Sight (BVLOS) Unmanned Aircraft (CAP 2533)

or 175Kt.[31] However, further evidence from trials will refine or modify this position to ensure that that all devices being used provide an appropriate level of safety.

2.15 The EC Consolidated Study Report also assessed antenna placement, finding no single optimal location across all airframes. Instead of mandating a placement requirement, the CAA will issue guidance to maximise EC performance while considering human factor hazards and other consistent factors including the attenuation of the human body. In the meantime, operators of CAP1391 equipment, particularly in aircraft constructed with signal-attenuating materials, should validate installation using future ground-based verification services. This process will be outlined further in the Ground Infrastructure (GI) policy concept paper.

2.16 The CAA is aware that CAP1391 does not currently specify a minimum transmitted power level for these devices. This will be rectified, taking into account current performance as well as our probability of detection studies and further encounter testing.

2.17 It is important to note that, to prevent significant additional congestion on the 1090MHz spectrum, this position encourages slower aircraft to equip with lower-cost CAP1391 devices, reducing unnecessary Mode-S transponder equipage. Studies suggest[32] that this will not create significant congestion if the rollout and spectrum is monitored, while maintaining safety and interoperability. The same report expects that the CAA will continue to monitor the 1090MHz spectrum.

Position 6. Any ADS-B – IN carriage for manned aircraft will remain a personal or organisational risk-based choice for the manned aircraft operator.

2.18 Setting policy for ADS-B In for manned aircraft presents significant challenges because of the wide range of variables, including:

- Certification differences in cockpit display equipment, ranging from fully certified, installed avionics to carry-on, off-the-shelf devices such as tablets and smartphones.
- Variability in communication hardware and software reliability between the EC receiver and the display device, from uncertified 2.4GHz wireless/Bluetooth connections to certified hard-wired systems.
- Inconsistencies in uncertified display technologies, including readability issues in bright cockpit conditions, affecting usability and situational awareness, and other environmental reliability issues.

[31] See TSO-C112f

[32] The EC Consolidated Study Report CAP3139

- ○ Differences in software certification levels and display iconography, leading to inconsistencies in how ADS-B In data is presented and interpreted by pilots.
- ○ Practical limitations for aircraft lacking cockpits, power supplies, or mounting locations, such as hang gliders, paragliders, and vintage aircraft.
- ○ Challenges in standardising see-and-avoid procedures, as crew response to UA detection on cockpit displays may vary, potentially leading to non-standard avoidance actions.

2.19 Notwithstanding the above challenges, as all pilots have a duty of care to prevent airborne conflict(s), it is recommended that pilots of manned aircraft should make use of ADS-B In where practical, whilst remaining cognisant of any limitations that may prevent the information being effectively utilised. It is also important to ensure that the use of any EC equipment does not introduce any new hazard into a cockpit environment.

Unmanned specific

Position 7. Within non - segregated airspace, UAS in the Specific Category operating BVLOS, must emit a 978 MHz UAT ADS-B signal. The device should function in accordance with the RTCA minimum performance standards DO-282B, (It is expected that DO-282C will be the standard from 2027) and of a minimum power yet to be set out within CAP1391 supplementary amendment 2025/01. Emissions must meet SIL and SDA of at least 1.

2.20 UAS must emit an EC signal in order that they can be detected and avoid other unmanned aircraft within their operational airspace. Manned aircraft operating in the same airspace may improve overall safety if they choose to receive and display the UAS' emissions. Beyond this direct detect and avoid functionality, the UAS emissions may also be used by ground-based systems to support other airspace management arrangements including:

- ○ A UTM service.
- ○ An independent emission in an emergency scenario such as a loss of control. e.g.; Squawk 7400
- ○ A lost C2 link message
- ○ An opportunity for a ground network to confirm the positions of UAS to increase the reliability and accuracy of the emitted EC signal

2.21 The required power output for UAS EC UAT transmissions will be determined using Multi UAT Model software, an ongoing program developed by QinetiQ. To ensure interoperability with ACAS sXu[33] (See also CAA DAA policy[34]), emissions must meet a SIL and SDA of at least 1.

2.22 In exceptional circumstances, to address specific safety issues, a 1090 MHz ADS-B emission may be acceptable by individual agreement with the CAA. Situations might include airspace that has a specific risk that requires regular mitigation. This may be a 1090 MHz emission only when a manned aircraft is detected within a defined proximity.

2.23 Specific category UAS, unless there is an airspace, safety or other compelling reason, **should not be equipped with a Mode-S transponder.**

2.24 It is assumed within these EC ConOps that the maximum airspeed for a Specific Category UAS will be 40 Metres per Second (approximately 78 kts).

Position 8. Specific category UAS operating BVLOS in non - segregated airspace must be equipped to receive ADS-B 1090 MHz and 978 MHz UAT in order to detect both manned and unmanned aircraft.

2.25 ADS-B IN on both 1090 MHz and 978 MHz is essential to perform detect and avoid in a volume of airspace where BVLOS UAS are operating. The processing of that data is of course equally important; ultimately, that data must be used to de-conflict with both manned and unmanned aircraft, be that by human intervention or an automatic system. This will also provide a means for UAS operators to comply with UAS Regulation 2019/947[35], with specific reference to the responsibilities of the remote pilot avoiding the risk of collision with any manned aircraft.

2.26 Equipment used to receive ADS-B must be reliable. Receiving equipment, both as part of an airborne system or as part of ground infrastructure must comply with applicable standards. For example, DO-260 and DO-282 set out equipment classes that set trigger (sensitivity) threshold levels. The link budget from transmitting equipment to the reception of ADS-B data must be considered when designing the EC system for a particular operation. Commercial feeds from internet services must not be used without addressing communication reliability and performance as part of the system.

2.27 By requiring the reception of both 1090 MHz and 978 MHz, CAA are seeking to ensure that BVLOS UAS can integrate safely with all airspace users while maintaining compliance with detect-and-avoid requirements. Operators should

[33] RTCA DO-396 - MOPS for ACAS sXU Functionality

[34] CAP3015

[35] UAS.SPEC.060 (3) (b) Responsibilities of the remote pilot

refer to the CAA DAA Policy[36] for guidance on Remain Well Clear (RWC) procedures and collision avoidance functions. It is recommended that RWC volumes should take account of any limitations in the performance of EC devices.

2.28 Due to results from research showing that pressure accuracy in a cockpit is known to have large errors in certain circumstances, any proposed UAS operation within 900 feet vertically of a manned aircraft, should consider these large errors and the associated risk and conduct their operation accordingly.[37]

Responsibility for EC Installation and Efficacy

Position 9. Aircraft operators, both manned and unmanned, are responsible for ensuring that their EC device is installed in accordance with the equipment manual and any CAA advice. Pilots must also ensure their device is functioning effectively.

2.29 The effectiveness of EC depends not only on equipage but also on proper installation and operation. For certified installations, these issues are catered for by existing regulations and procedures. However, and especially for uncertified EC equipment, our research identified that incorrect installation, particularly poor antenna placement, taking into account aircraft occupants and other factors will significantly impact the performance of EC devices.

2.30 Ensuring proper installation is important for UAS, where reliance on EC for situational awareness is crucial in BVLOS operations. Similarly, for General Aviation (GA) and commercial operators, incorrect installation could lead to less than optimum signal propagation from and to the equipment, limiting the benefits of EC in airspace integration.

2.31 As such, CAA will expect operators to follow best-practice guidelines for antenna and device installation, including device quality indicator and other software settings. Routine verification of device functionality should be performed. Further guidance and industry best practices will be developed by the CAA to support compliance and ensure that EC systems contribute effectively to airspace safety.

[36] CAP3015

[37] See appendix B '*The EC Consolidated Study Report*'

Chapter 3

Taking EC Forward – Next Steps & Priorities

3.1 The implementation of EC in the UK is a short, medium and long-term strategic initiative, requiring continuous validation, industry collaboration, and technological evolution. This section provides information on our structured approach for developing, testing, and refining EC policy to ensure safe and effective integration into UK airspace. This plan is divided into short-term objectives (2025-2027), focusing on testing, validation, and initial implementation, and a longer-term strategy (2027 and beyond), which aims to enhance EC technology and expand its operational use.

Short term focus and test phase (2025 - 2027)

Validation of proposed position and assumptions

3.2 The positions detailed in this document and the assumptions that these are built upon must be validated through real-world testing and research. While we have used contemporary studies, further testing is required to ensure that assumptions hold true in operational environments. We plan to use industry trials to refine policy decisions and assess EC's role in the UK.

3.3 For example, as part of this work, ongoing testing and research will help us better understand effectiveness of EC as a mitigation to a series of risks. These studies will be conducted in collaboration with industry stakeholders to ensure that findings are applicable across various airspace environments and operational scenarios. If the TRA trials do not fully answer specific questions, additional studies may be commissioned.

3.4 Several key areas have been identified for further exploration, including:

- Air-to-air encounters at tactical collision avoidance range, as defined in CAP3015, Section 4.3. These will include:
    - UAS carrying a 1090 MHz receiver interacting with a CAP1391 1090 MHz transmitter on a manned aircraft.
    - UAS carrying a 1090 MHz receiver interacting with certified ADS-B 1090ES equipment on a manned aircraft.
    - UAS transmitting via a low-power 978 MHz UAT, with the manned aircraft receiving on 978 MHz.
- Air-to-ground to support strategic planning and encounter sets including:

- Reception of UAS transmitting low power 978 MHz UAT
- Reception of manned aircraft transmitting CAP1391 1090 MHz

The ground infrastructure project is working up its own set of testing and research which will be available via that ConOps.

3.5 The outcomes of these trials and studies will directly inform CAA policy, ensuring that EC delivers the required safety mitigations to support the safe integration of new technologies into UK airspace.

Consultation on the EC ConOps

3.6 The positions outlined in this ConOps are published for consultation in July 2025 to test our assumptions, gather expert insights, and ensure the policy is robust, proportionate, and operationally viable. Stakeholders are invited to share their views on each of the proposed positions, as well provide any broader comments on the role of EC in the UK. In parallel, we are also using this consultation to gather early evidence to inform a potential EC mandate. Full details, including how to respond, can be found on our dedicated consultation website.

Training for the use of EC and Installation Guidance

3.7 Effective EC use requires both operator training and proper installation to maximise safety and performance. The CAA will develop training and guidance materials based on findings from the EC Consolidated Study Report, and other relevant studies, to ensure EC is used effectively by both manned and unmanned aircraft operators.

Training for EC Use

3.8 The CAA will implement a structured training and awareness programme to support operators in understanding EC functionality, limitations, and best practices as part of the EC programme.

3.9 CAA to promulgate user safety advice to ensure that operators in non - segregated airspace operation:

- Apply most appropriate EC mode for flight phase to manage workload produced by non-urgent alerts.
- Are aware that EC symbology on moving map display will take longer to interpret in some display cases.

Installation Guidance

3.10 The effectiveness of EC devices depends significantly on correct installation, placement, and orientation. Findings from the EC Consolidated Study Report[38] indicate that externally mounted antennas can provide better performance, but placement on certain airframe materials can lead to signal shadowing and reduced effectiveness. In parallel with the structured training programme above, operators will have access to advice which will address proper installation.

Future Improvements

3.11 To improve installation verification, the CAA is investigating post-installation antenna pattern and emission analysis, as recommended by the EC Consolidated Study Report. A contractor-led study in 2025 will explore the practical implementation of this analysis to help operators assess their EC system performance after installation.

3.12 The CAA ground infrastructure workstream is studying this aspect of work.

Longer Term Strategy (2027 and beyond)

3.13 In an ideal world, setting out policy for EC would follow a structured approach where strategy leads to requirements for operational, functional and finally a technical requirement. The motivation to achieve our shorter-term goals drives us to realise the advantages of existing EC solutions and motivates us to use existing standards and technology.

3.14 Beyond 2027, the focus will shift towards enhancing EC technology and expanding its role in airspace modernisation, with particular focus on UK-AM/4 (Integration) and UK-AM/7 (Future Surveillance)[39]. Efforts will include working with industry on the development of next-generation EC devices and improving its incorporation with the UK’s air traffic management system.

3.15 The CAA believes that EC devices and specifications available today can enable a certain level of mitigation to address the immediate aims of industry. The learnings from the short-term strategy will inform the requirements for future equipage.

3.16 Future equipage may impact current assumptions for 978 MHz and any changes will need to be cognisant of current sharing arrangements with Ofcom. This may need to be re-visited at that time.

[38] CAP3139, *The EC Consolidated Study Report*

[39] CAP 1711a Part 2 Airspace Modernisation Strategy 2023-2040

3.17 This document aims to reflect and record this learning as it iterates, proposing modifications to present and future policy as appropriate.

Transmitting Devices – Manned and Unmanned Aircraft

3.18 A key long-term objective is to develop a set of robust EC devices suitable for both manned and unmanned aircraft. To improve interoperability, it is desirable that future devices will use the 1090/978 spectrum. UK-AM4 (Integration) and UK-AM/7 (Future Surveillance) sets out a strategy that includes 'interoperability of EC with new ACAS systems (Hybrid/ACAS X)'. The strategy also sets out 'Shared EC data, of required integrity, to support integration'. The integrity required for the short-term goals is set out in our positions. Higher integrity solutions will be required to enable data to support Flight Information Services (FIS) and Air Traffic Services (ATS) separation, including the likely requirement for a level of certification.

3.19 While the AMS sets out the longer-term aspirations for EC, the findings from operations using the short-term positions for EC will inform the technical detail required to meet the goals set in UK-AM/4 and 7.

3.20 Example EC RCE NTD specifications may include:

- High reliability and quality of emissions, suitable for integration with air traffic services as set out in UK-AM4 and 7.
- Certification standards enabling installation on certified and uncertified airframes.
- A range of interoperable devices tailored for different aircraft types, from sport aircraft to more complex GA operations, as well as specific and possibly certified category UAS.
- Affordability across all airspace users, ensuring widespread adoption.
- Antenna diversity to mitigate airframe and human body masking, as recommended in the EC Consolidated Study Report (Chapter 4, Conclusion 2).
- A review of the ADS-B standards including the adoption of ADS-B V3 (DO-260C).

Chapter 4
Conclusion

4.1 EC represents a critical step in the modernisation of UK airspace, supporting both safety enhancements and the integration of new airspace users. This document has outlined our key positions on our approach to the technical requirements for EC here in the UK.

4.2 It is clear that EC alone will not solve all airspace safety challenges, but it will provide a significant and scalable tool for improving airspace awareness, supporting DAA functions, and enabling a more connected and data-driven airspace system.

4.3 Continued engagement with all our stakeholders will be essential to ensuring EC delivers its full potential as a key enabler of future airspace safety and efficiency. This document will continue to evolve as we gather industry views, test feasibility, completeness and gather further evidence.

APPENDIX A

Strategic and Regulatory Drivers for EC

A1 The implementation of EC within the UK is shaped by a range of strategic, regulatory, and policy influences. These drivers provide the foundation for the CAA's work and guide the long-term strategic direction of EC policy.

A2 This section summarises key international and national frameworks, including ICAO Global Air Navigation Plan (GANP), the UK Airspace Modernisation Strategy (AMS), and the UK Future of Flight Action Plan. Each of these documents contributes to defining the role of EC in airspace safety, detect-and-avoid (DAA) functions[40], and broader airspace integration objectives.

A3 Many of the referenced documents are publicly available, and so only a high-level summary is provided. For those that are not, a more detailed synopsis is included to ensure transparency in how these policies influence EC development.

ICAO GANP

A4 To meet the UK's international obligations, the AMS aligns delivery with the ICAO Global Air Navigation Plan (GANP) and ensuring interoperability of the UK network with neighbouring air traffic management areas. The Global Air Navigation Plan (Doc 9750) is the ICAO's highest air navigation strategic document and the plan to drive the evolution of the global air navigation system, in line with the Global Air Traffic Management Operational Concept (GATMOC, Doc 9854) and the Manual on Air Traffic Management System Requirements (Doc 9882). The AMS therefore incorporates elements of the GANP that are relevant to the strategic policy direction for UK EC.

A5 The GANP uses a guiding deployment framework known as the Airspace System Block Upgrade (ASBU) with workstreams organised into 'threads' and 'elements'. While the ASBU threads have extensive operational and technical descriptions, not everything will be wholly applicable to the UK, while some activities necessary for modernisation of UK airspace will be specific to the UK. The delivery elements in the strategy are therefore based on ICAO operational and technical descriptions but tailored to the needs of UK airspace.

[40] CAP3015 – DAA policy concept

A6 The delivery elements form the basis of research and development activities over the near term in support of deployment, including how those activities are funded. The delivery elements also identify legislative, policy or regulatory gaps that need to be addressed, for example how to accommodate new types of aircraft in UK airspace like remotely piloted aircraft systems. This EC ConOps embodies this method by proposing an initial position and continuing to work with industry to ensure a workable solution through the short-term concept test phase, through to a longer-term business as usual, including potential changes to legislation and policy.

The UK Airspace Modernisation Strategy

A7 The UK Airspace Modernisation Strategy (AMS) part 1 sets out strategic objectives and enablers for the modernisation of UK airspace out to 2040. Part 1 sets out the objectives of the AMS. One objective is the ‘Integration of diverse users’, and its ambition to “enable the widest possible use of electronic conspicuity”. The strategy sets out visions for future air traffic services which include EC and mentions that EC “will be required to enable ‘detect and avoid’ for all airspace users”

A8 CAP1711A sets out part 2 of the AMS which details deliverables. Both deliverable 4 (integration) and deliverable 9 (aircraft capabilities) reference new collision avoidance systems which will have EC dependence.

A9 Part 3 of the AMS sets out that DAA policy will use the UK Specific Operating Risk Assessment (SORA) which will create a framework for EC to provide a risk mitigation. EC strengthens the “fundamental safety principle of ‘see and avoid’ by adding the ability to ‘detect and be detected’.”

UK Future of Flight action plan

A10 The Action Plan sets out a joint plan, co-designed by industry and Government, for a Future of Flight ecosystem that will deliver maximum value to the UK: its economy, its environment and its citizens. It sets out a shared vision for 2030 along with some delivery timelines. The most significant (for this document) of those is Strategic Objective 3 (SO3) – routine BVLOS operations in non - segregated airspace by 2027. It presents the parts that the government, the CAA and industry will need to play to make our common goals a reality. The aspirations of the action plan align with medium term goals of the AMS.

A11 The action plan makes little mention of existing aviation, focussing instead on new industry. Our EC ConOps document must take into account the needs of all airspace users and consider the benefits of EC for all.

APPENDIX B

Summary of evidence and reports used to support our positions

B1 This section provides an overview of key evidence drawn from a range of reports, studies, and findings conducted since 2015. The review of this data was required to reach our conclusions on the direction the CAA intends to take on the equipage of EC today, and into the future, to enable greater safety and integrate new technology into UK airspace.

EC Consolidated Study Report (2024) (CAP3139)

B2 The EC Consolidated Study Report carried out in 2024 was conducted in five main workstreams. Each workstream contained separate studies which fed the main report. Workstream Six brought the studies together into one report. The subjects studied were:

Workstream One

B3 The aim was to assess the potential limits of use of both ADS-B frequencies. Initial conclusions included that 1090 MHz was modelled to be suitable until 2040, and 978 MHz until 2050. This does need to be closely monitored as the associated SSR use of 1090 MHz/1030 MHz has been known to approach critical levels when providing a surveillance service to commercial air transport. In addition, there was no receiver model included in the study, so the above 1090 conclusion only includes the secondary radar environment. A receiver study is due to commence during 2025.

Workstream Two

B4 The goal was to model the typical radiation pattern of EC devices with antennas mounted in varying positions, both inside and outside of the airframe. There was also a ‘human body study’ which modelled, and live measured the attenuation caused by the human body; considering the occupants of a light aeroplane or a paraglider or hang glider. Conclusions included that an external antenna, while exhibiting some advantages, is not a panacea for the reception of an EC device. Internal antennas also exhibit some advantages if they are sited correctly. It is clear that EC, in almost every configuration, provides an imperfect mitigation for mid-air conflict, however it provided some level of confidence for the level of mitigation that can be provided. The study made recommendations on potential future improvements for training and equipage.

Workstream Three

B5 Examined two regions of the UK to establish a representative and quantitative characterisation of the airspace risk in the UK, focusing specifically on the risk of mid-air collision. This characterisation captured all classifications of airspace and considered the variety of airspace users and the complexity of their operations in the UK. This quantitative analysis gives a greater understanding of the airspace risk today, which paves the way for future means of compliance to UK SORA requirements.

B6 This work provides evidence that an airspace risk study could provide a route to evidencing the mitigation that EC could bring to a BVLOS operation when integrating manned and unmanned airspace users.

Workstream Four

B7 Provided a concept of how technology might operate within the airspace construct. It proposed a modular approach that can scale as the airspace risk changes for differing operations. These ranged from the simple air to air model to a more complex model that offered features such as:

- GNSS jamming and spoofing detection
- Position, Navigation and Timing (PNT) denied backup function
- A method of relaying a backup position back to airborne assets
- A method of passing data to an Unmanned Traffic Management (UTM) service provider and / or the UAS operator

B8 The airspace architecture study paves the way for a Ground Infrastructure (GI) implementation that is the subject of another workstream. It is intended that the EC ConOps is read along with the GI concept.

Workstream Five

B9 Studied the Human Factors (HF) aspects of (mainly) the reception of an EC signal and how the human in the loop deals with the data that they may receive while operating either manned or unmanned aircraft. It also reviewed the challenges of displaying EC data in cockpits due, in part, to the high ambient lighting of those environments. Recommendations included a focus on the training of remote pilots and the design of display equipment.

Summary Paper

B10 Brought together all the reports above into a consolidated summary, while retaining the detail of the recommendations and the reasons for them. It links the workstreams and proposed further work that should be carried out in the future. This summary report is available as CAP3139.

The 'Egis' report 2022 – CAP2498[41] A, B and C – Minimum EC standards

Phase 1: Assessment of the current environment and existing standards concluding in a high-level recommendation for a future approach.

B11 This report scored the many options available to enable the aims of the AMS. The highest score was 3A as below:

B12 "3A Adopt existing global standards for regulated EC devices. Manned aircraft - 1090 ES (Out minimum), Unmanned 978 UAT In/Out.""

B13 "Mandate the use of regulated EC devices (ADS-B) for all airspace users requiring IFR services (enhanced FIS with Surveillance) or operating in Class A, C, segregated airspace blocks, or operating unmanned BVLOS

B14 Building upon current equipment fits, existing user types maintain with 1090 MHz (Out minimum) devices, new user groups (UAS) equip with 978 MHz. Adopts existing global standards for regulated EC devices. Encourage other users to adopt regulated EC devices through safety arguments & access to restricted airspace blocks. UAS would always be required to avoid manned aircraft. Additional regulation development required to enable entry of new user operations (i.e. BVLOS or UAS segregated airspace) and use of 978 UAT within UK."

Phase 2: Assessment of the recommended approach from Phase 1 with industry stakeholders to define the future environment.

B15 The report covers the cost vs performance balance and the data quality vs certification. It states that an 'enhanced' EC device will have minimal certification despite calling for better quality indicators being transmitted. "The device certification process should follow the existing CAP1391 EC device procedures to minimise the administration burden." The Egis phase 2 report proposes an 'enhanced' EC solution, for which specification does not exist apart from an aspirational specification within the report. This specification (set out in section 2.7 and 3) may inform the basis of a future standard to enhance the utility of EC.

[41] https://www.caa.co.uk/our-work/publications/documents/content/cap2498a/

Phase 3: Definition of the regulatory standards and regulatory framework required to proceed with the implementation of the minimum technical standards for EC and associated surveillance in the UK to cover both Air to Air, Ground to Air and Air to Ground.

B16 The phase 3 report recommends a way forward, including:

B17 Working with OFCOM to licence 978 MHz

B18 Studying aspects of low power DF-18 ADS-B devices including the probability of detection

B19 Assurance and accuracy testing

B20 A GNSS integrity solution

B21 Updating of various CAA policies

B22 The CAA has taken on board the recommendations above and has enacted or is in the process of enacting all of them.

Mode-S transponder and EC equipage

B22 Detailed configurations and levels of EC equipage in UK airspace are unknown. To gain some understanding of equipage, the CAA commissioned a study in the summer of 2024 to pool together and analyse EC data from aircraft under 5700KG MTOW, in the forms of ADS-B, MLAT, FLARM & Pilot Aware data from the CAA's Airspace Analyser Tool.[42] The data infers that equipage rates have increased since 2018, with a significant proportion of the UK GA fleet equipped with an EC transmitting device, ADS-B being the majority EC emission found.

B23 One of the risks of our proposed Concept of Operations is that we encourage more aircraft to equip with mode-s transponders (reference the 1090MHz congestion report within the EC Consolidated Study Report), that risks loading more traffic onto an already congested 1090 MHz frequency. However, the data we have does not suggest that our positions will result in more aircraft fitting transponders in large numbers. We can infer a rough proportion of GA aircraft that have fitted transponders, and other types of EC devices, from the following synopsis from this study:

[42] For a fuller explanation of the tool, see page 7 of this separate CAA report https://www.caa.co.uk/publication/download/20519

Caveats

B24 There are many caveats to the data in this study, therefore, some conclusions involve experience and assumption.

B25 Number of G registered aircraft under 5700kg MTOW in CAA Statistics

B26 CAA Aircraft Register Statistics - As of 1st Jan 2024 – 18861 (subtract 1175 aircraft greater than 5701kg) = 17686 G registered aircraft 5700kg MTOW or under.

Proportion of G-registered aircraft that have been EC conspicuous on ADS-B, FLARM, Pilot Aware or MLAT from 2018 to July 2024.

B27 This data includes emissions from aircraft that had ADS-B from transponders with extended squitters, CAP1391 devices, FLARM, Pilot Aware (PA) devices and transponders in UK-registered aircraft,

B28 Using the CAA published aircraft register statistics, we can see the number of G registered aircraft within the 0-5700kg MTOW weight category has slowly declined by almost 5% between 2018 and 2024. The study showed 11266 G registered aircraft were detected at least once in the Analyser Tool in the dates specified. When comparing this to the number of G registered aircraft in the stats above (17686 as of 1st Jan 2024), we can say that roughly 64% of G registered aircraft under 5700kg MTOW have been electronically conspicuous between 2018-2024 (using ADS-B, FLARM, PA, Mode S transponder detected via MLAT, or a combination of these).

B29 Another thing we wanted to consider was how regularly was EC being used in UK airspace, which is something the G register does not tell us. GA pilots report their flying hours to the CAA when their permit to fly or certificate of airworthiness for their aircraft expires. From the 2024 data (which only had data going to the end of June), we saw that 9298 aircraft had reported flying hours greater than 0. From these 9298 aircraft, 7248 aircraft were electronically conspicuous at least once in the analyser tool. From this we can reasonably assume that 78% of aircraft that had flown 1 or more hours in UK airspace had EC in 2024. We also obtained a very similar result for 2023 and 2022, which tells us that over three quarters of the aircraft that report their hours regularly use EC.

Proportion of G registered aircraft that have ONLY ever been detected by Multilateration (MLAT) from 2018 to July 2024?

B30 Multilateration (MLAT) is a method of deducing the location of transponder only equipped aircraft. A total of 1095 aircraft out of the 11266 aircraft detected in the Analyser Tool since 2018 have ONLY ever been detected via MLAT, which equates to around 10% However we know that the number of transponder only equipped aircraft is likely to be higher. We have seen evidence of this from the work down at

Goodwood aerodrome from their approved Flight Information Display, and the Traffic Information Service Broadcast trial.

CAA / DfT EC Rebate figures

B31 We can infer some indication of the appetite to fit mode-s transponders from our statistics that recorded the devices claimed for during the rebate scheme. Of the ADS-B capable devices, CAP1391 devices accounted for 4771 claims. ADS-B capable transponder claims, both including a GNSS source and without, amounted to 400, so 8.8%. For interest, another 190 claims were made for GNSS position sources. All other devices amounted to 2570.

Conclusions regarding equipage

B32 It is important that we do not encourage a large jump in transponder equipage as a result of our set positions. Only a small number of the very large proportion of operators that choose to emit some sort of EC do so with a mode-s transponder only. A very small proportion of operators took advantage of the EC rebate scheme to fit a transponder. Perhaps because of the widespread existing equipage. Almost all mode-s transponders on the market are capable of an extended squitter. Further, it is known that faster aircraft are often better equipped, and most will already be fitted with a mode-s transponder.

GASCO [43]HF report

B23 A study commissioned by the CAA in 2022 to look at the human factors of EC use for GA pilots by GASCO. This study[44] set out the challenges of the EC equipage landscape with several key conclusions.

B24 The likelihood of detecting another aircraft via EC is less than 50% assuming the devices are in range and 90% equipage due to a huge range of incompatible EC devices.

B25 The chances of being detected vs detecting other aircraft are infinitely variable, depending on the equipment and quality of the installation.

B26 Research has showed that visual range for see-and-avoid is between 1 and 2 miles with a maximum of 3 miles depending on conditions.

[43] General Aviation Safety Council - https://www.gasco.org.uk/

[44] CAP2583 – GASCO Human factors report

Aviation Innovation Centre report on Altitude Reporting

B27 ADS-B can emit both GNSS altitude above the Geoid[45], as well as pressure altitude referenced to the standard (1013.2Hpa). CAP1391 allows both emissions. The standard emission and data processing carried out is the standard pressure altitude. Transponder equipped aircraft which emit ADS-B based on their extended squitter are connected to the static source provided by the aircraft. This source of pressure is part of the certified requirements of the aircraft, depending on the standard that the aircraft is certified to. It will provide an accurate pressure value for the transponder to report via ADS-B.

B28 A CAP1391 device has the option of being a carry-on device. This device will sense the cockpit static pressure of the aircraft. A trial carried out by Trax at the Aviation Innovation centre at Goodwood found that, especially in faster aircraft, the cockpit static can be significantly below the actual static pressure for the level being transited (see table). This results in the carry-on ADS-B device reporting an inaccurate ADS-B level which is higher than actual aircraft level. This phenomenon occurred in faster aircraft. The most significant was an inaccuracy of approximately 700’ when flying at around 220 knots in a fast, aerobatic aircraft.

	MAX IAS	**MAX BARO-ALT DIFFERENCE**
DA42	164	105
EXTRA300	220	788
CABRI G2	96	218
PA28	114	58
C172	126	NA
PIPER CUB	120	16

B29 This constitutes one of the two main reasons that we intend to limit the carriage of carry-on ADS-B devices to slower aircraft when operating in non-segregated airspace. Another option may be to use a GNSS height above geoid which is allowed within CAP1391. Additional work is needed to determine how safe and effective this might be. However, it is preferable to use a single altitude datum if possible. CAP3015 tackles this within the data integrity section (5.13) that within

[45] Ordnance Survey - guide-coordinate-systems-great-britain – 3.1.4

Arcs b-d, a common altitude reference should be used for all traffic. In the short-term the CAA intends to retain pressure altitude reporting.

B30 Calculation of the maximum cockpit static variation at 140kt (an approximate and provisional calculation is 868ft based on the inverse dynamic pressure at ISA). This calculation requires verification, as well as practical evaluation through testing.

CAP1391[46]

B31 CAP1391 sets out the evolution of EC policy in the UK. The document focusses on improving the situational awareness of pilots flying manned aircraft by setting a design specification for such devices. There are three standards listed within the document. Those standards deal with the operation and functional level of the device, rather than the performance of any transmission or reception. CAP1391 is out of date in several areas, and the intention is to update and modernise in the short term. It is likely to be replaced in the longer term.

B32 The document sets out an original 'design brief' which the Electronic Conspicuity Working Group[47] set out as a suitable set of design elements that would encourage the voluntary uptake of a 1090 MHz ADS-B EC device. That design brief included elements such as its size, weight and power, easy antenna fit, minimum regulatory hurdles, its interoperability, the device alerting methods and price, as well as its ease of operation. Section 6 in CAP1391 deals with the technical specification of an EC device section and references the DO260 RTCA standard, with some exceptions, including the power emitted.

B33 It is interesting to note that, even in its most recent update in 2021, there is no mention in the document of UAS, or any other reference to un-manned aircraft or eVTOL. The document's aim was entirely to increase the situational awareness of general aviation in uncontrolled airspace.

B34 The CAA has produced a supplementary amendment to CAP1391 to include the use of 978 MHz UAT for air-air use.

[46] CAP1391 – 'Electronic conspicuity devices'

[47] CAP1391 - 'The establishment of an Electronic Conspicuity Working Group'

APPENDIX C

Regulatory, Technical and Airspace Integration Considerations for EC

C1 The successful deployment of EC in UK airspace requires careful consideration of regulatory, technical, and operational challenges. This annex provides further details on the key factors that have influenced our positions set out in this EC ConOps, ensuring that all requirements are fully understood.

Licence exempt vs. aviation spectrum

C2 Some electronic conspicuity devices use 'Licence Exempt Short Range Device' (SRD) frequencies. These devices have provided many aircraft operators with an EC function for many years. Some systems support ground networks that receive their transmissions and, in some cases, re-transmit data to airborne receivers.

C3 Within Europe, EASA has announced the use of SRD 860[48] within U-Space. U-Space is a volume of airspace where a U-space service provider collects all EC emissions, from 1090 MHz ADS-B (978 MHz is proposed), as well as EC emissions from LTE (4G data) devices and ADS-L. ADS-L is a technology that uses hardware to transmit, in parallel with existing systems proprietary EC signals, a set of parameters set out in an EASA technical specification. This data will be used by the U-Space service provider to provide a strategic deconfliction service to new entrants such as UAS as well as other, existing airspace users. The U-Space service provider will collect data from all sources, including Remote ID, and mobile phone apps to provide a strategic deconfliction service.

C4 In the UK, the DfT and CAA have made a joint decision to use aviation protected spectrum (1090 / 978 MHz) to provide some similar elements of U-Space, but also an air-to-air, tactical concept of collision avoidance. The advantages of using an aviation segregated spectrum to provide this service (compared to using SRD860) are as follows:

- That the highest power available within OFCOM's IR2030 for airborne use is limited to orders of magnitude lower levels than available with ADS-B.

[48] ADS-L 4 SRD860 Issue 1

- That OFCOM cannot guarantee a lack of interference within any one part of the 860 band. "Most General Non-Specific Short Range Device allocations are located in bands also used for industrial, scientific and medical apparatus (ISM), so may suffer from interference in certain locations."
- That the CAA and other aviation bodies have much less control over the design and certification requirements for devices on ISM bands, especially over competing technologies that may use the same bands for other purposes.
- That (apart from the ADS-L specification), the protocols used for many of the EC devices are closed and proprietary.
- The lack of international interaction of airborne systems
- The lack of air-to-air interoperability with different systems (e.g mobile comms / ADS-L / ADS-B devices)

C5 Of course, there are some disadvantages with using aviation spectrum. One is that the equipment must be licenced and another is that, especially on 1090 MHz, the frequency is subject to congestion.

C6 The UK has already set out within CAP670 supplementary amendment 2021/02 the use of a range of EC device inputs. "Note: EC sources in a non-aviation protected band can be used to supplement [ ] for situation awareness only and must not be used to supplement the provision of Flight Information Services.

C7 FID02.7[49] A multi-source FID shall differentiate through symbology, colour or labels between ADS-B equipped aircraft, Mode-S equipped aircraft and data from other sources (e.g., EC sources operating outside of the protected aviation spectrum)."

Equipment standards – manned aircraft

C8 Limiting the discussion to technologies that operate within protected aviation spectrum, there are two operating frequencies for ADS-B technologies – 978 MHz and 1090 MHz.

C9 RTCA DO-260 is the international standard MOPS for the operation of ADS-B on 1090 MHz. This standard is referenced in both CAP1391 and TSO-C166. These are the two equipment specifications that are in use worldwide at present for ADS-B on 1090 MHz. The three main categories of emissions on ADS-B available within the UK are:

49 Cooperative Surveillance Systems & Flight Information Displays

C10 CAP1391: These devices operate to an 'uncertified' standard of ADS-B equipment. They are low radio frequency emitted power (up to 40W) and have a requirement for lower quality indicators compared to some certified equipment. This equipment features a Downlink Format 18 (DF-18) which signals to equipment receiving this signal that the transmitting device is not a transponder and cannot therefore reply to interrogations. ICAO have updated their Doc 9871 to include the indication of 'reduced capability devices', which will be included in an update to CAP1391 to meet the ICAO document definitions.

C11 Certified Mode-S transponders (but uncertified GNSS source): These feature an extended squitter that emit data from an uncertified, off-the-shelf GNSS source. This equipment features a Downlink Format 17 (DF-17) which signals to equipment receiving this signal that the transmitting device is connected to a transponder, and so is available to reply to interrogations.

C12 Certified Mode-S transponders (with certified GNSS source): These feature an extended squitter that emit in accordance with TSO-C166 and are connected to a certified GNSS source certified to TSO-C145. There is another standard of GNSS position source. This source is a TSO-C199c (also DF-17) which is the lower-level TABS certification.

C13 Quality indicators relating to the equipment standards above are discussed separately in the section below.

C14 At present, there are no 'certified' EC devices operating on 1090 MHz featuring DF-18. This means that, to fit a certified 1090 MHz device to an aircraft, it must be attached to a transponder. As we have seen in the EC Consolidated Study Report, encouraging a widespread uptake of more transponders is not recommended due to possible congestion of the 1090 MHz frequency. The Egis report suggested designing a new standard of 'enhanced EC device'. EC Consolidated Study Report mentions that there is no possibility of designing this device and the standards surrounding it in the short-term. The report suggests enhancing the performance of a CAP1391 device, where required, using a ground network. This is a strategy that the CAA endorse and is an option for higher risk airspace in the longer term, along with the development of these DF-18 devices.

Quality indicators and certification of ADS-B standards

C15 ADS-B quality indicators set out to report the reliability and accuracy of the ADS-B emission. Some ground and airborne safety nets such as some certified airborne receivers and some ATC processing systems will not display low quality emissions. It is important to consider these quality indicators when designing an approach to EC that addresses as many opportunities for system interaction as possible, especially for longer term system planning.

C16 This document deals with two main ADS-B quality indicators:

C17 SIL (Source Integrity Level) is used to define the probability of the reported horizontal position exceeding the radius of containment defined by NIC (Navigation Integrity Category, which sets out the horizontal containment bounds of – normally – a GNSS source)

C18 SDA (System Design Assurance) The probability of transmitting false or misleading information

C19 The following discussion relates to ADS-B 1090 MHz V2 (DO260B) and UAT V2 (DO282B).

C20 There are three main considerations for ADS-B quality indicators.

- ○ The regulatory requirements surrounding operations in differing airspace risk categories.
- ○ The interaction with various receiving sensors and processors including airborne sensors and ground sensors.
- ○ The real-world accuracy and how that effects the DAA safety case.

CAP1391 ADS-B devices

C21 CAP1391 specifies an SDA and SIL1 if the position source is certified to TSO-C199. If the position source uses an uncertified GNSS receiver, the quality indicators must all be set to the lowest possible (0). It is likely that CAP1391 will be modified to specify the use of SIL and SDA > 1 devices in the future.

Transponder based devices

C22 CS-STAN[50] CS-SC005b comprises a useful summary of the available systems for 1090 MHz – set out in its three cases:

- ○ Configuration 1: an ADS-B OUT system that conforms to AMC 20-2414;
- ○ Configuration 2: an ADS-B OUT system with a GNSS position source that is authorised in accordance with Class B ETSO-C199;
- ○ Configuration 3: an ADS-B OUT system with a GNSS position source that is not approved.

C23 The likelihood of erroneous data being transmitted to ADS-B ground stations and to other aircraft is defined by quality indicators.

[50] Initial Airworthiness Adopted CS-STAN Issue 4.pdf

C24 A Configuration 1 installation provides quality indicators according to the principles that are defined in AMC 20-24 while controlling the latency through a direct connection between the transponder and the GNSS position source.

C25 A Configuration 2 installation provides quality indicators that are defined in ETSO-C199.

C26 A Configuration 3 sets the quality indicators to zero (0). Operators of aeroplanes fitted with a configuration 3 installation are expected to use the system for traffic awareness only. ADS-B information sent from equipment emitting with quality indicators that are set to zero (0) might not be seen by other aircraft systems or by ATC.

Quality indicators set out in FAA Title 14 CFR 91.227

C27 The FAA sets out the performance requirements to satisfy its ADS-B mandate. They essentially require a certified installation in any certified airframes; TSO-C166b and TSO-C154c for ADS-B1090 MHz and 978 MHz UAT respectively. In Experimental airframes, there is a slight alleviation, in that TABS, or TSO-C199 GNSS source can be used to output SIL3/SDA2. In the rest of the world, a TABS GNSS source SIL/SDA must be set to 1. The regulatory reason for this anomaly has not been determined to date.

978 MHz UAT quality and certification standards

C28 978 MHz UAT is designed as an EC standard from the outset. It’s implementation, as set out in DO-282B/C uses a similar subset of messages as 1090 MHz ADS-B. In the USA, the FAA require equipment to be certified to TSO-C154c. However, they are using that emission on certified airframes to provide an air traffic separation service. The UK are aiming to equip UAS with UAT on 978 MHz for tactical collision avoidance in varying levels of airspace risk in the short term.

Discussion

C29 The lowest quality indicators, as set by uncertified GNSS sources for transponders and some CAP1391 devices using off-the-shelf GNSS sources are intended for use primarily for increasing the situational awareness for the pilots of manned aeroplanes. However, a study by the EC Interoperability Testing Programme (report only available as a slide pack) showed that existing CAP1391 devices ‘demonstrate accuracy that satisfies required performance’.

C30 There is an argument that the accuracy and to a certain extent the latency of uncertified devices are not critical in lower risk (certainly ARC-B, possibly ARC-C) environments. However, because it is more likely that the accuracy and latency are a much greater factor at high closing speeds, this is another reason to suggest a speed limit when emitting lower quality indicators. The DAA Policy Concept Consultation Document CAP3015 discusses this:

> "ADS-B includes several data quality metrics which may be used to estimate real-time position reporting accuracy, including Navigation Accuracy Category position (NACp) and Navigation Accuracy Category velocity (NACv). These values are typically based on GNSS Horizontal and Vertical figures of merit (HFOM and VFOM). If such values are not available, then CAP3015 discusses an approach for estimating uncertainty based on the GNSS provided Horizontal Dilution of Precision (HDOP). […] If such real-time accuracy monitoring is not available, then an appropriate increase to NMAC and RWC volumes may be considered as an alternative."

C31 A benefit of higher quality indicators is that more ground and airborne systems can receive, process and display aircraft emissions. Most flavours of ACAS Xa for example requires SIL3 for hybrid surveillance. Some ACAS devices will however provide some functionality with a SIL1 emission. ACAS sXu is a particular interest, as it is likely that some smaller UAS will use this standard of collision avoidance as a comprehensive DAA solution that is set out in DO-396. Simplified minimum quality parameter values for ADS-B sensor inputs for sXu are as follows:

C32 NACv = 1, NIC = 6, SDA = 1, SIL = 1, ADS-B version must be 2.

C33 There are very few certified airborne or ground-based air traffic systems that will process ADS-B data in any way if the quality indicators are zero.

C34 For the reasons above, the CAA recommend that the minimum quality values transmitted in volumes of airspace that allow BVLOS should be at least SDA = 1 and SIL = 1.

C35 For future aspirations of EC, the output of compliant quality indicators would be beneficial for interaction with certified platforms. A system for 1090MHz EC devices similar to the TSO-154C standard for UAT and it's deployment by the FAA in the USA is a model. This would ideally allow a SIL = 3 etc to be transmitted and allow full interoperability with airborne and ground systems.

Detect and Avoid (DAA)

C36 Detect and Avoid is essentially the system that replaces the pilot's see-and-avoid function in a manned aircraft environment. The system will use technology to produce a method of detecting and then avoiding other aircraft.

C37 As part of the EC discussion, we must consider, at the fundamental level, the time an operator needs to react to a calculation that two aircraft are on a collision course and to avoid that collision. This leads to the derivation of the surveillance volume requirement for cooperative aircraft. It is acknowledged that non-cooperative DAA is feasible, however, the AMS calls for cooperative DAA using EC.

C38 CAP3015 – the Detect and Avoid Policy Concept Consultation document provides a range of metrics and requirements for a DAA implementation. The EC system needs to provide a minimum range of detection so that the operators or systems involved will have time to manoeuvre to avoid a potential collision. There is an aspiration for this detection range to be provided today, with extant technology. There are some precedents for those distances required set out in the DAA policy concept.[51] Additional points of reference are set out below. Please note that these scenarios give a range of opinions, but that CAP3015 sets out the CAA's policy concept on this subject:

Scenario one:

C39 This scenario assumes equipage of an EC device, with the manned aircraft operating at 140 kts and 80 kts for the unmanned aircraft. The aircraft are on a direct head on trajectory at the same height. With a closing speed of 220 kts, to achieve a 30 second warning before impact, the minimum range of detection would be 1.8nm ((30sec = 0.0083) hours x 220 kts)).

Scenario two:

Quote from the FLARM website:

> "What is the minimum required range for a timely warning?
>
> When flying at or below 250 kt, a range of 2 nm (3704m) forward and 1 nm to the side and behind will give the pilots a warning at least 15 seconds before closest convergence. Any range beyond that may be useful for tactical purposes but it adds very little to safety. Calculation:
>
> Worst case below 10 000 ft is normally two aircraft converging at 250 kt each -> 500 kt closing speed -> 257 m/s.
>
> For a 15 second warning -> 3858 m -> 2.08 nm
>
> The profile of a glider when seen from straight ahead at 2 nm distance is about as thick as a human hair held at arm's length; almost impossible to see…"

[51] CAP3015 Sect 4.18 sets out additional DAA timeline examples.

Scenario three:

C40 If we wish to compare the performance of un-certified, carry-on EC with see and avoid, several[52] studies show that the un-cued maximum visual range for spotting another manned aircraft with a good lookout technique is around 3Nm. More usually, the other aircraft is spotted at round the 1.5Nm range. This gives a much shorter time to react if the speeds involved are high. However, the coupling of the reaction for a direct visual separation is likely to take less time than processing of EC data to avoid a collision. An ASTM DAA performance standard (F3442/F3442M − 23, Standard Specification for Detect and Avoid System Performance Requirements) suggests a remote pilot processing delay of 15s for situation awareness & decision making.

DAA requirements

C41 CAP3015 sets out a range of requirements for the assurance of DAA systems as appropriate for different Air Risk Categories (ARCs):

- Residual ARC-a – no DAA capability is required
- Residual ARC-b and ARC-c – Here the document sets out the requirements for performance, reliability, availability, data integrity, assurance and oversight, including for EC in this 'medium risk' airspace.
- Residual ARC-d – High risk, possibly commercial, IFR operations where manned aircraft requirements and certified equipment will be required.

C42 This means that, based on a set of DAA requirements, overall requirements for the function of an EC device can be determined, including minimum ranges for certain encounter speeds and proximities.

C43 In addition, UK SORA[53] sets out the air risk model characterisation process which plays a part in linking EC and DAA policy concepts to the air risk classes.

C44 However, there is a requirement for all parties to equip to a set equipment standard, as it is inconvenient and costly to equip to different standards for different airspace risks. This document makes proposals for EC equipage to service the most common operational requirements for as many different scenarios as possible.

[52] One example - https://www.atsb.gov.au/sites/default/files/media/4050593/see_and_avoid_report_print.pdf

[53] AMC1 Article 11 Conducting a UK Specific Operation Risk Assessment (UK SORA)

Strategic vs. tactical conflict management

C45 Electronic Conspicuity, in its basic form is a simple concept. Once an aircraft has transmitted its location and state vector, the operator in receipt of that data can visualise that transmission, using the information to avoid proximity with the transmitting aircraft. For UAS, this can be used to replace the concept of see and avoid. See and avoid is known to be flawed (many research papers – here is one from the ATSB[54]) as a mitigation to MAC due to the limitations of cockpit visibility, limitations of pilot technique and limitations of the human eye. These limitations could be compared to some of the limitations of EC.

C46 UAS.SPEC.060(3) sets out the responsibilities of the remote pilot. (3)(b) of that regulation states that pilots must "avoid any risk of collision with any manned aircraft and discontinue a flight when continuing it may pose a risk to other aircraft, people, animals, environment or property;". There are two main methods of using EC to avoid a risk of collision – Tactical and Strategic.

C47 To ensure that conflicts can be managed appropriately, the ICAO manual of UAS Operations (DOC 10019) states "The detectability and conspicuity of RPA will have to be sufficient to ensure timely identification by other airspace users and ATC in all phases of flight (including ground operations). Timely detection (by visual or electronic means) will ensure that the rules of the air can be applied safely."

Tactical collision avoidance

C48 Most contemporary EC equipment was designed for use in uncontrolled airspace with tactical, short term, air-to-air collision avoidance in mind, with the intention of improving the situational awareness of manned aircraft, especially in uncontrolled airspace. FLARM, for example was originally designed only to warn aircraft operators specifically when there is an imminent likelihood of a collision. According to one FLARM device operating manual: "The first warning level for another aircraft or an obstacle is delivered when less than 18 seconds remain to the possible collision; the second warning level is delivered when less than 13 seconds remains; the third level when less than 8 seconds remains."

C49 One of the reasons for the short warning periods is that legacy FLARM units only transmit at 25mW power, which means that they had relatively short range. Despite this, short warning times seem to have had a very positive effect on collisions between gliders in the UK and worldwide.[55]

[54] See and Avoid | ATSB

[55] Ventus-2CT_G-KADS__E1-Antares_G-CLXG_06-24.pdf this accident report provides some useful data.

C50 CAP1391 also refers to FLARM in its scope: “EC devices are intended to offer similar functionality to FLARM but using the 1090 MHz airborne spectrum.”

Strategic deconfliction

C51 Strategic deconfliction could take many guises. A pre-flight tool could be used to provide that strategic deconfliction, much like CADS provides a service for (mainly) military flight crews to deconflict with other crews. EC could also provide an input into a medium term strategic deconfliction system, or indeed, operators can, today strategically deconflict themselves from other operators due to the EC picture in-cockpit if they have the ability to detect other aircraft with sufficient range.

C52 The CAA proposes that EC provides a combination of collision avoidance methods. An air-to-air tactical deconfliction method will provide one risk mitigation, while infrastructure that receives EC transmissions will serve to provide a strategic deconfliction service, similar to U-Space. Both methods will provide mitigations, but the air-to-air solution is the mitigation that is the focus.

C2 link and EC

There is a separate stream of work that sets out the CAA policy for command and control (C2) links to UAS. This policy will contain elements of EC, including the ability for the C2 link to carry EC data and the reliability and certification metrics required in each case. There may be a function that is required from EC in the case of lost C2 link that may form part of a UAS safety case.

In the latest RTCA specification for UAT (DO-282C) there is an ‘Emergency and priority status’ field. This field includes ‘lost link’ reporting, which means that the EC device is reporting that the UAS has lost the C2 link. It is likely that the C2 ConOps will call on that function and the CAP 1391 supplementary amendment indicates that DO-282C will be the required standard in 2027.

Airspace architecture and Electronic Conspicuity

C53 The AMS has a long-term aspiration that EC will provide a comprehensive suite of benefits for airspace users. How EC fits into the UK airspace system is an important element of airspace architecture, which influences this EC ConOps.

C54 The EC Consolidated Study Report[56] Series sets out a range of architectures that cater for the wide-ranging levels of airspace risk found in the UK. At its very basic level, the architecture relies on an air-to-air EC architecture. It is important to note that the use of uncertified EC may only provide limited mitigation to MAC. As the airspace risk increases, the level of complexity, and involvement of

[56] CAP3139

Ground Infrastructure grows to increase the mitigation provided by the whole system.

C55 The airspace architecture will be dealt with by a separate policy concept. This will set out the required technical and operational solutions to ensure safe integration of UAS into airspace. The policy will be dependent on the airspace (air) risk in a specific area, which results in an adaptable technical airspace architecture depending on the level of risk in the specific airspace. The EC Consolidated Study Report sets out the conclusions from its risk analysis thus:

"It is estimated that in certain scenarios (e.g. some uncontrolled airspace at very low altitudes or some low-level portions of under-utilised controlled airspace), the effective use of EC data as a primary mitigation source may be able to effectively support the safe integration of BVLOS for UAS. However, in other scenarios (e.g. most controlled airspace and aerodromes), it is estimated that EC (including EC data) may not suffice as a primary mitigation source, in which case 'heavier' mitigations (or a combination of) would likely be required." Therefore, the exact level of mitigation that some EC provides is unknown beyond well informed assumptions.

- EC can provide mitigations for operations in the following categories:
  - Flight information to and from an ANSP
  - Traffic awareness for manned aircraft
  - DAA by RPAS
  - Limited utility for some TCAS displays for manned aircraft (limited to display on some systems – no TA or RA with ADS-B alone)

C56 Further work as part of the EC project, including testing and research, will look to better quantify the mitigation performance. This research will form part of the CAAs industry engagement during the TRA trials, and potentially additional studies if the TRA trials cannot answer this specific question.

ICAO 24-bit addresses

C57 All registered, manned aircraft are assigned a unique ICAO 24-bit address, which stays with each aircraft for its life. These addresses are not recycled if an aircraft is destroyed or otherwise de-registered. At present UAS or un-registered manned aircraft or other airspace users e.g. parachutists that carry an ADS-B device are allocated addresses on an individual basis by the National IFF/SSR Committee (NISC).

C58 24-Bit addresses are fundamental to how EC works. Unique addresses are critical to decode the vast number of transmissions and differentiate what information is being broadcast by whom. Without strict controls, surveillance systems may reject duplicate addresses and render EC ineffective. Direction is therefore required on the issuance of 24-Bit addresses to UAS and users of RCE (CAP1391 devices).

C59 The following recommendations have emerged as temporary solutions to solve an immediate problem whilst a more permanent solution making safe and effective use of non-ICAO 24-Bit addresses is evaluated.

C60 Certified category UAs expected to operate in CAS or in proximity to traditional manned aircraft should be issued ICAO 24-Bit AAs for use in Mode S transponders (with ADS-B Out) as part of their certification or registration.

C61 Specific Category UAs may require an ICAO 24-Bit address in exceptional circumstances depending on the use case. Where an ICAO 24-Bit address allocation is deemed necessary for the safe operation of the flight, the address may be allocated as part of the UK SORA and registration processes. UA that equip with UAT will be expected to make use of self-assigned temporary (non-ICAO) 24-Bit aircraft address as per DO-282().

C62 Open Category UAs should not be allocated an ICAO 24-Bit address. Where necessary, by exception only, this category of UA may be required to use UAT which can make use of self-assigned temporary (non-ICAO) 24-Bit aircraft addresses as per DO-282.

Aircraft ID (call sign) setting

Aircraft Identification (ACID) is traditionally defined as the aircraft callsign or registration as per Item 7 of an ICAO flight plan. In Universal Access Transceivers, this is known as the Callsign ID (CSID), and it provides the same information as for Mode S transponders and ADS-B Out.

Aircraft Identification is a separate data item to the 24-Bit aircraft address and should not be confused. 24-Bit aircraft addresses are programmed to each EC device and are necessary at a technical level for surveillance systems to differentiate aircraft transmissions. ACID on the other hand may be used many times operationally to differentiate aircraft on a particular flight (e.g. BAW123 may be used by different aircraft on separate days). The use of Callsign ID on UAS has yet to be decided upon.

Planning and Monitoring of the 1090 MHz and 978 MHz environment

C63 (EC ConOps study series - chapter 3, conclusion 1,2,3) It is important that during any deployment of 1090MHz ADS-B, the 1090 MHz radio environment is continually monitored to ensure that it's efficacy for the use for EC and existing systems including radar, WAM and airborne safety nets. There are a host of commercial receivers that may be able to perform that monitoring role. However, the EUROCONTROL 'EMIT' (European Monitoring of Interrogators and Transponders) receiver network already exists in the most heavily loaded region around London. The EMIT network is due to be expanded in collaboration with CNS&S colleagues, which should provide the monitoring required for the 1090 MHz environment.

C64 Related to the radio environment monitoring, it will also be important to continue to monitor the deployment of 1090 MHz devices, including growth and decline in certain aviation sectors. This monitoring should also take into account any congestion mitigation involving radar and related systems, as well as transponder technologies.

C65 A work strand to plan and then monitor the 978 MHz environment will be required. The scope of this work will depend on the deployment scale of 978 MHz airborne and ground devices.

Validation of EC against jamming and spoofing

C66 All contemporary EC devices that include a position report within their emission currently rely on a GNSS receiver to supply a source of position and timing. Unfortunately, at the time of writing, a huge proportion of the CAA's Mandatory Occurrence Reporting (MOR) involves a loss of GNSS integrity due, in part to the increasing prevalence of GNSS jamming and spoofing attacks. These attacks centre mainly around zones of conflict: at present not around the domestic landmass of the UK. However, a preliminary overview of MORs reveal that GNSS jamming and spoofing attacks in UK airspace appear to be increasing. In the last year, there have been around 30 suspected cases reported via the MOR system. The data at present is not completely reliable, so the CAA is investigating and sponsoring research into this subject. We also have evidence from other domestic monitoring systems that GNSS is attacked on a smaller scale for the purposes of crime or other nefarious reasons very regularly. This is obviously a major obstacle to many of our plans, and results in a risk that we must consider. CAP3015 sets out its policy on data integrity thus:

- Residual ARC-B: Independent validation of EC tracks is not required unless GNSS jamming, spoofing, and / or intruder track spoofing is identified as a specific risk for the operating area.
- Residual ARC-C: Independent validation of EC is required, and the DAA system (and own ship position, navigation and timing) must be resilient to GNSS jamming and spoofing by design, unless the operating environment is such that this risk is agreed as acceptable by the CAA.

C67 For a particular operating environment, there is likely a need to review & identify any GNSS jamming / spoofing risks before considering this against likely duration & available mitigations. Even without specific GNSS jamming / spoof risks identified there is value in validation to provide a cross check of reported position accuracy if the airspace risk profile demands this. The specifics of any ground based multilateration and GNSS quality reporting system will be referenced in the Ground Infrastructure policy concept.

Integration of non-cooperative / anonymous traffic

C68 There will be a requirement to integrate some traffic that cannot be obliged by statute to equip to the standards set out in any EC policy. One example is military aircraft; especially those who are operating in the UK low level system who do not emit ADS-B. An alternative method will be required if mitigations for these operations against BVLOS UAS and potentially other electronically conspicuous operations are required. This will become a challenge for any possible future general and widespread BVLOS operations within UK airspace.

C69 Some categories of aircraft are required to remain anonymous. An example might be the National Police Air Service or other government agency, both operating UAS or manned aircraft. In common with non-cooperative traffic, these aircraft will be required to tactically mitigate their operations from BVLOS and other electronically conspicuous operations.

C70 These aircraft must make every effort to receive emissions from other aircraft in order to contribute to the airspace safety case.

Ground Infrastructure

C71 The following elements (among others) of the EC strategy will be set out in the CAA's ground infrastructure policy concept document, and are not dealt with in this document:

- EC receiving infrastructure to enhance the reliability of reception of low power devices
- Multilateration technology to provide a backup positioning service

○ Electronic obstruction beacons to notify “cluster-based” activities such as large model sites, paragliding and hang-gliding activity, where electronic conspicuity of individual air systems is not practicable or desirable.”

- ○ A Traffic Information Service Broadcast” (TIS-B) that will re-broadcast aircraft locations
- ○ An EC emission quality measuring tool for aircraft

APPENDIX D

Consultation Questions

D1 This consultation seeks feedback on the positions set out in the Initial Technical ConOps for EC.

D2 You will be asked to provide your views on each of the proposed positions with regard to how it delivers on the ConOps's two aims:

- enhancing manned aircraft situational awareness; and
- enabling detect-and-avoid for Unmanned Aircraft Systems (UAS).

D3 You do not need to respond to every positon in the ConOps, so please focus on the areas most relevant to your expertise or operations.

D4 We encourage all respondents to read the full ConOps document before completing the consultation.

About you

1. Are you responding in an official capacity on behalf of an organisation?
   - Yes
   - No

   If yes, please tell us its name
2. What is your name?
3. What is your email address?
4. Are you answering as:

   Please select all that apply
   - Unmanned Aircraft Pilot/ Operator
   - Member of the General Aviation community
   - Member of the commercial aviation industry
   - Central or local government body including military
   - Elected political representative e.g. councillor or MP
   - National representative organisation e.g. trade association

- ○ Resident affected by aviation
- ○ Local organisation e.g. community action group
- ○ Other

If other, please specify

5. If you are a member of the General Aviation community, which sub-category are you answering as?

   Please select all that apply

- ○ Aerodrome
- ○ Balloon
- ○ Fixed-wing 0 - 2 Tonne MTOW
- ○ Fixed-wing 2+ Tonne MTOW
- ○ Glider / TMG
- ○ Hang gliding / Paragliding / Paramotoring
- ○ Helicopter
- ○ Microlight
- ○ Model aircraft
- ○ Other - please specify below

If other, please specify

6. If you are from the commercial aviation industry, which sub-category are you answering as?

   Please select all that apply

- ○ Airline
- ○ Airport
- ○ Air Navigation Service Provider
- ○ Business Aviation
- ○ Other - please specify below

If other, please specify

7. What, if any, EC Device do you currently use?

8. Do you consent to your response being published on this consultation website?

   (Required)

   Please select only one item

   - ○ Yes, with personal identifying information (name, organisation, respondent category, location, additional information - please note your email address will NOT be published if you choose this option)
   - ○ Yes, anonymised
   - ○ No

The Role of EC in UK Airspace

You will be asked to provide your views on each of the proposed positions with regard to how it delivers on the ConOps's two aims:

- ○ enhancing manned aircraft situational awareness; and
- ○ enabling detect-and-avoid for Unmanned Aircraft Systems (UAS).

You do not need to respond to every position in the ConOps, so please focus on the areas most relevant to your expertise or operations.

9. Position 1. EC will be an enabler for both air-to-air tactical and strategic deconfliction within non - segregated airspace. Tactical deconfliction will be the primary mitigation, while strategic deconfliction will enhance risk management. Ground infrastructure will enhance both mitigations where appropriate

   To what extent, if at all, do you agree or disagree that this position supports the two primary objectives of this Initial EC Technical ConOps?

   Please select only one item

   - ○ Strongly Agree
   - ○ Tend to Agree
   - ○ No strong feelings either way
   - ○ Tend to Disagree

- Strongly Disagree
- Don’t know

Please explain your answer and provide any other general comments.

EC Device Standards

You will be asked to provide your views on each of the proposed positions with regard to how it delivers on the ConOps's two aims:

- enhancing manned aircraft situational awareness; and
- enabling detect-and-avoid for Unmanned Aircraft Systems (UAS).

You do not need to respond to every position in the ConOps, so please focus on the areas most relevant to your expertise or operations.

10. Position 2. The overall performance of the EC system will be enhanced, where appropriate through a combination of interoperable airborne and ground-based systems that build on existing architecture.

    To what extent, if at all, do you agree or disagree that this position supports the two primary objectives of this Initial EC Technical ConOps?

    Please select only one item

    - Strongly Agree
    - Tend to Agree
    - No strong feelings either way
    - Tend to Disagree
    - Strongly Disagree
    - Don’t know

    Please explain your answer and provide any other general comments.

Airspace Architecture

You will be asked to provide your views on each of the proposed positions with regard to how it delivers on the ConOps's two aims:

- enhancing manned aircraft situational awareness; and
- enabling detect-and-avoid for Unmanned Aircraft Systems (UAS).

You do not need to respond to every positon in the ConOps, so please focus on the areas most relevant to your expertise or operations.

11. Position 3. EC with an appropriate level of accuracy and performance set out in this document, will aspire in the short term, to support operations for the following:

    - DAA by Unmanned Aircraft
    - Where equipped, position information to and from some ANSPs (or future UTMSP – policy under development).
    - Traffic / situational awareness for manned aircraft
    - Some limited interaction with traffic collision avoidance system (TCAS) for manned aircraft

    To what extent, if at all, do you agree or disagree that this position supports the two primary objectives of this Initial EC Technical ConOps?

    Please select only one item

    - Strongly Agree
    - Tend to Agree
    - No strong feelings either way
    - Tend to Disagree
    - Strongly Disagree
    - Don't know

    Please explain your answer and provide any other general comments.

Equipage requirements

You will be asked to provide your views on each of the proposed positions with regard to how it delivers on the ConOps's two aims:

- enhancing manned aircraft situational awareness; and
- enabling detect-and-avoid for Unmanned Aircraft Systems (UAS).

You do not need to respond to every position in the ConOps, so please focus on the areas most relevant to your expertise or operations.

12. Position 4. Within non - segregated airspace, aircraft operating at <140 knots (Kts) Indicated Air Speed (IAS) must use 1090MHz ADS-B devices emitting a SIL and SDA of at least 1, such as (for example) some CAP1391 devices. Alternatively, a TSO-C112 and TSO-C166 compliant transponder with extended squitter connected to TSO-C199 class B or TSO-C145 Global Navigation Satellite System (GNSS) source.

To what extent, if at all, do you agree or disagree that this position supports the two primary objectives of this Initial EC Technical ConOps?

Please select only one item

- ○ Strongly Agree
- ○ Tend to Agree
- ○ No strong feelings either way
- ○ Tend to Disagree
- ○ Strongly Disagree
- ○ Don't know

Please explain your answer and provide any other general comments.

13. Position 5. Within non - segregated airspace, aircraft operating at >140kts IAS must use a Mode S transponder with ADS-B Extended Squitter functionality and SIL = 3, SDA = 2, typically a TSO-C112 and TSO-C166 compliant transponder connected to a TSO-C145 GNSS source.

To what extent, if at all, do you agree or disagree that this position supports the two primary objectives of this Initial EC Technical ConOps?

Please select only one item

- ○ Strongly Agree
- ○ Tend to Agree
- ○ No strong feelings either way
- ○ Tend to Disagree
- ○ Strongly Disagree
- ○ Don't know

Please explain your answer and provide any other general comments.

14. Position 6. Any ADS-B – In carriage for manned aircraft will remain a personal or organisational risk-based choice for the manned aircraft operator.

To what extent, if at all, do you agree or disagree that this position supports the two primary objectives of this Initial EC Technical ConOps?

Please select only one item

- ○ Strongly Agree

- ○ Tend to Agree
- ○ No strong feelings either way
- ○ Tend to Disagree
- ○ Strongly Disagree
- ○ Don’t know

Please explain your answer and provide any other general comments.

15. Position 7. Within non - segregated airspace, UAS in the Specific Category operating BVLOS, must emit a 978MHz UAT ADS-B signal. The device should function in accordance with the RTCA minimum performance standards DO-282B, (It is expected that DO-282C will be the standard from 2027) and of a minimum power yet to be set out within CAP1391 supplementary amendment 2025/01. Emissions must meet SIL and SDA of at least 1.

    To what extent, if at all, do you agree or disagree that this position supports the two primary objectives of this Initial EC Technical ConOps?

    Please select only one item

    - ○ Strongly Agree
    - ○ Tend to Agree
    - ○ No strong feelings either way
    - ○ Tend to Disagree
    - ○ Strongly Disagree
    - ○ Don’t know

    Please explain your answer and provide any other general comments.

16. Position 8. Specific category UAS operating BVLOS in non - segregated airspace must be equipped to receive ADS-B 1090MHz and 978MHz UAT in order to detect both manned and unmanned aircraft.

    To what extent, if at all, do you agree or disagree that this position supports the two primary objectives of this Initial EC Technical ConOps?

    Please select only one item

    - ○ Strongly Agree
    - ○ Tend to Agree
    - ○ No strong feelings either way

- Tend to Disagree
- Strongly Disagree
- Don't know

Please explain your answer and provide any other general comments.

Responsibility for EC Installation and Efficacy

You will be asked to provide your views on each of the proposed positions with regard to how it delivers on the ConOps's two aims:

- enhancing manned aircraft situational awareness; and
- enabling detect-and-avoid for Unmanned Aircraft Systems (UAS).

You do not need to respond to every position in the ConOps, so please focus on the areas most relevant to your expertise or operations.

17. Position 9. Aircraft operators, both manned and unmanned, are responsible for ensuring that their EC device is installed in accordance with the equipment manual and any CAA advice. Pilots must also ensure their device is functioning effectively.

To what extent, if at all, do you agree or disagree that this position supports the two primary objectives of this Initial EC Technical ConOps?

Please select only one item

- Strongly Agree
- Tend to Agree
- No strong feelings either way
- Tend to Disagree
- Strongly Disagree
- Don't know

Please explain your answer and provide any other general comments.

Additional Comments on the EC Concept of Operations

18. Do you have any additional comments or concerns regarding the EC Concept of Operations?

Call for Evidence on the EC Mandate

The UK Government has asked the CAA to begin work on exploring how EC mandate may be introduced in the UK, separate from this Concept of Operations. The questions below seek early stakeholder input on the potential challenges, and opportunities of introducing a potential EC mandate for lower airspace users. This work would not apply to larger aircraft over 5.7 tonnes, as these are, in most cases, already required to carry and utilise an ADS-B Out capable Mode S transponder in accordance with Commission Regulation (EU) No. 1207/2011.

19. In principle, do you support or oppose the introduction of a potential EC Mandate for lower airspace users in the UK?

    Please select only one item

    - ○ Support
    - ○ Neither
    - ○ Oppose

    Please explain your answer and provide any other general comments.

20. 20What operational, financial, or technological barriers, if any, do you foresee with a potential EC Mandate? Please detail your answer.

21. 21What opportunities, if any, do you foresee with a potential EC Mandate? Please detail your answer.

22. 22What data, studies, or evidence are you aware of, that should be considered in the development of a potential EC Mandate?

23. 23What other views, if any, on the potential introduction of an EC Mandate should the CAA consider at this early stage?